CHAPTER 3

INTERNAL COMBUSTION ENGINES

This chapter is designed to help you understand the maintenance and repair of internal combustion engines. You as an EN2 should be able to describe the basic procedures used to test and repair diesel engines. Also, you should be able to identify the procedures used to troubleshoot diesel and gasoline engines. This chapter will cover the general procedures used to repair and overhaul gasoline engines; the procedures used to inspect, test, and repair jacking gear; and the procedures used to troubleshoot and repair fuel and oil purifiers.

To help ensure that an engine will operate efficiently, you must follow its preventive maintenance schedule. By following the preventive maintenance schedule, you will reduce engine casualties and help the engine achieve its normal number of operating hours between overhaul periods.

When you must finally perform an engine repair or overhaul, take the following precautions:

- Plan the work in definite steps, so you can perform it smoothly.
- Have the necessary tools and parts on hand before you begin a repair or overhaul.
- Have the necessary forms ready to record the clearances, dimensions, and other vital measurement readings that must be kept as part of the engine's history.
- Always check precision measuring instruments before you use them; then recheck your readings. The first reading may not be correct.
- Keep the work area clean. Do not allow oil to accumulate on the deck or on the tools. Place the tools or parts neatly away from the immediate area.

The test, maintenance, and repair procedures presented in this chapter are general in nature. The specific procedures vary with different engines. Before you begin a maintenance or repair procedure, consult the manufacturer's technical manual or the equipment's preventive maintenance schedules. They are valuable sources of information on tests, maintenance, and repairs.

INSPECTING AND TESTING THE ENGINE FRAME OR BLOCK

Before you begin an inspection or test, make sure the outside of the engine is cleaned thoroughly. This will help you spot cracks, leaks, and other problems more easily than if the engine is dirty. By cleaning the engine, you will also help prevent dirt and other contaminants from entering and damaging parts and accessories of the engine.

Some of the inspections and tests you may perform are listed in the following sections.

VISUAL INSPECTIONS

Inspect the top surface of the cylinder block, the top and bottom crankcase flanges, and the oil pan for warpage. You can use a straightedge, a feeler gauge, and a good light. Figure 3-1 illustrates how to use a straightedge and a feeler gauge to check the top surface of the cylinder block Compare your measurements to the manufacturer's specifications to determine if the surface is warped.

Visually inspect the cylinder block for cracks, breaks, or other damage.

MEASUREMENTS

Visually inspect the engine block's bolts to determine if they are bent, broken, or worn.

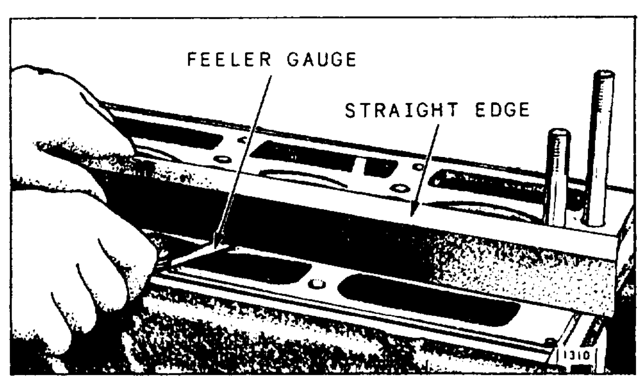

Figure 3-1.—Checking the top surface of a typical cylinder block.

Measure the bore in the cylinder block, with a dial indicating bore gauge, to determine if wear or an out-of-round condition exceeds the manufacturer's specification. Figure 3-2 illustrates the use of a bore gauge to measure a cylinder bore. You can use an inside micrometer as well, but a dial indicating bore gauge is easier to use.

Inspect and measure the engine block's hold-down bolt holes. Use a telescoping snap gauge to determine if wear has caused enlargement of the holes. If a telescoping snap gauge is not available, try to move each bolt from side to side with your fingers. If a bolt moves from side to side, its hole has enlarged and must be repaired. Always follow the manufacturer's instructions on how to correct a hole enlargement problem.

DYE PENETRANT TEST

Conduct a preliminary dye penetrant test on the engine block's surface to identify cracks that you cannot see otherwise. Be sure to follow the manufacturer's instructions on how to conduct this test. Remember that only a certified nondestructive testing technician can perform a dye penetrant test that meets the requirements of quality assurance.

AIR AND WATER PRESSURE TESTS

Test the cylinder block for cracks in the cylinder bores between the water jacket and the oil passages by using either air pressure or water pressure. The purpose of each test is to pressurize the water Jacket to the point, within safe limits, that leaks show.

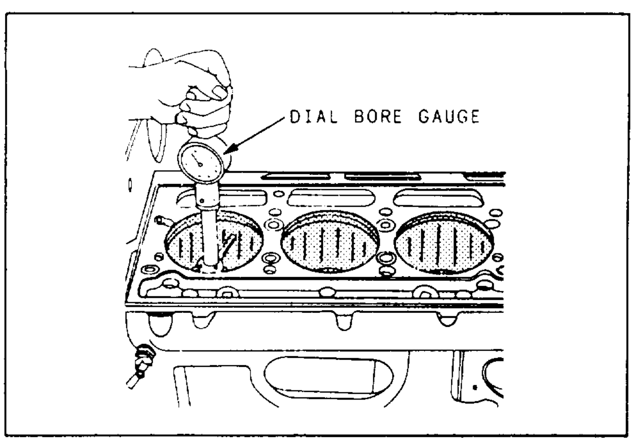

Figure 3-2.—Checking the cylinder bore for wear or out-of-roundness.

Air Pressure Test

Before you perform the air pressure test, make sure you completely strip and clean the block. Then, follow these basic procedures:

1. Seal all of the block's freshwater passages with gaskets and flanges.

2. Connect a low-pressure air hose to a fixture on one of the flanges.

3. Immerse the block into a tank of water heated to the engine's normal operating temperature. Allow the engine to soak for approximately 20 to 40 minutes, as specified by the manufacturer. This allows the block to warm to the temperature of the water.

4. Apply approximately 40 psi of pressure to the block and watch for bubbles. Bubbles indicate a crack or leak in the block. Determine what repair is needed or can be made when you identify the source of the bubbles.

If you cannot dip the block, you may still perform the air pressure test. Attach the hose to a fixture secured to an opening to the water jacket. Pressurize the water jacket. Carefully spray soapy water over the block and look for air bubbles caused by the pressurized air.

Water Pressure Test

The water pressure test is similar to the air pressure test, except that defects are indicated by water leaks rather than by air leaks. Before you perform the water pressure test, strip and clean the block Then, follow these procedures:

1. Seal off all but one of the freshwater openings with flanges and gaskets. Make seals airtight.

2. Fill the water jacket with fresh water until all air is purged from the water jacket. Seal the fill opening with a flange that contains an air hose coupling.

3. Attach an air hose and pressurize the water jacket to approximately 40 psi (see the manufacturer's manual). Maintain the pressure in the water jacket for at least 2 hours.

4. Inspect the cylinder bores, air box, oil passages, crankcase, and cylinder block exterior for the presence of water. The presence of water at any of these locations indicates that the water jacket has one or more defects.

REPAIRING THE ENGINE FRAME OR BLOCK

Some engine block repairs are cost efficient, while others are not. The following paragraphs briefly discuss basic repairs to the block itself. Later paragraphs discuss repairs to block components.

LEAKING WATER JACKET

Most engine blocks that have a leaking water jacket are not worth the cost to repair. To determine if such a block can be repaired economically, consult the appropriate MILSTD and technical manuals for the engine.

WARPED CYLINDER BLOCK OR CRANKCASE FLANGES

You may use a hand surface grinder to correct small amounts of surface warpage. Do not remove more metal than necessary. The manufacturer's manual will specify how much metal you may remove with the hand grinder. If the warpage exceeds the maximum allowed for hand grinding, send the block to the machine shop for machine grinding.

WORN BOLT HOLES

Over a period of time, bolt holes may become oversize due to wear from threading and unthreading the fasteners. You may correct a worn bolt problem by one of three primary methods, depending on the situation.

1. If the bolt hole is slightly oversize, you may be able to simply use a larger bolt in the hole, if such use is authorized for the component the bolt fastens down.

2. If enough metal remains around the hole, you may be able to install a helicoil. Check the helicoil installation instructions and appropriate technical manuals to determine whether or not a helicoil is acceptable.

3. You may also till the hole with weld metal and then drill and tap a new hole.

Whatever method you use to correct the problem, always check the bolt and bolt hole for proper fit.

INSPECTING, TESTING, AND REPAIRING CYLINDER LINERS

Cylinder liners may become damaged or worn excessively. The following paragraphs discuss the more common causes and repairs.

CRACKED, BROKEN, AND DISTORTED LINERS

You should suspect one or more cylinder liners whenever you notice one of the following indications:

- Excessive water in the lubricating oil
- An accumulation of water in one or more cylinders of a secured engine
- An abnormal loss of water in the cooling system
- High cooling water temperature or fluctuating pressure (caused by combustion gases blowing into the water jacket)
- Oil in the cooling water

When you suspect that a liner is cracked, try to locate the cracks visually. If you cannot locate the cracks visually, use another testing method, such as the water pressure test or air pressure test described earlier. To check liners with integral cooling passages, plug the outlets and fill the passages with glycol-type antifreeze. This liquid will leak from even the smallest cracks.

Cracks in dry liners may be more difficult to locate because there is no liquid to leak through the cracks. You may need to use magnaflux equipment or penetrating dye to locate these cracks.

Causes

Cylinder liners may crack because of poor cooling, improper fit of piston or pistons, incorrect installation, foreign bodies in the combustion space, or erosion and corrosion. Improper cooling, which generally results from restricted cooling passages, may cause hot spots in the liners, resulting in liner failure due to thermal stress. Scale formation on the cooling passage surfaces of liners may also cause hot spots; wet liners are subject to scale formation. You may remove the scale by following the procedures outlined in chapter 233 of the Naval Ships' Technical Manual (NSTM).

Proper cooling of dry liners requires clean contact surfaces between the liners and the cylinder block. Particles of dirt between these surfaces cause air spaces, which are poor conductors of heat. Films of oil or grease on these mating surfaces also resist the flow of heat.

Distortion, wear, or breakage may result if a liner is not properly seated. Causes of improper liner seating may be metal chips, nicks, or burrs, or improper fillets, In figure 3-3 an improper fillet on the cylinder deck prevents the liner from seating properly. To correct an

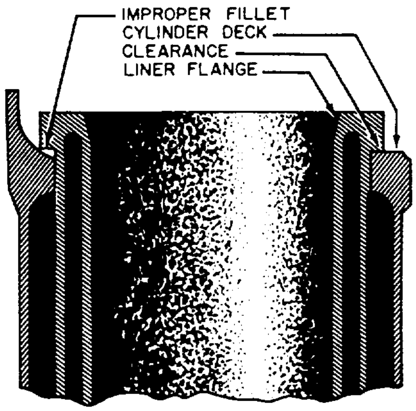

Figure 3-3.—Improperly seated cylinder liner.

improper fillet, grind it down until the lower surface of the flange seats properly on the mating surface of the cylinder deck.

An oversized sealing ring may cause improper positioning of the liner. As the sealing ring is overcompressed, the rubber loses its elasticity and becomes hard, which may cause the liner to become distorted.

Use feeler gauges to check the clearance between the mating surfaces. If the manufacturer's technical manual specifies the distance from the cylinder deck to the upper surface of the liner flange, use this dimension to check on the seating of the liner.

Obstructions in the combustion chamber may be destructive not only to the liner but also to the cylinder head and other parts.

Erosion and corrosion may take place in a few isolated spots and weaken a liner sufficiently to cause cracks.

Repairs

Replacement is the only satisfactory means of correcting cracked, broken, or badly distorted cylinder liners.

SCORED CYLINDER LINERS

Scored cylinder liners may become scored (scratched) by several means. These scratches degrade the engine's performance and require some type of repair.

Scored cylinder liners may be caused by broken piston rings, a defective piston, improper cooling, improper lubrication, or the presence of foreign particles or objects. Dust particles drawn into an engine cylinder will mix with the oil and become an effective but undesirable lapping compound that may cause extensive damage. The importance of keeping the intake air clean cannot be overemphasized.

Another precaution you should take is to make sure that when you replace a cylinder head, you leave no metal chips, nuts, bolts, screws, or tools in the cylinder.

Causes

Scoring may be in the form of deep or shallow scratches in the liner surface. With most liner scoring, there will be corresponding scratches on the piston and piston rings. The symptoms of scoring may be low firing or compression pressure and rapid wear of piston rings. The best method for detecting scoring is visual inspection through liner ports, through the crankcase housing with pistons in their top position, or when the engine is disassembled.

Badly worn pistons and rings may cause scoring because blowby of combustion gases increases the temperature of the liner and may reduce the oil film until metal-to-metal contact takes place. Inspect the pistons and rings carefully. A piston with a rough surface (such as one that has seized) will score the liner.

Scoring as a result of insufficient lubrication or dirt in the lubricating oil can be prevented if lubricating equipment (filters, strainers, and centrifuges) is maintained properly. Lube oil must be purified according to required procedures.

Repairs

Ship's force personnel normally do not repair scored liners; they replace them with spare liners. When necessary, liners with minor scoring may be kept in service, if the cause of scoring is eliminated and the minor defects can be corrected. The surface of the liner must be inspected carefully, especially in the region next to the ports, for any burrs, projections, or sharp edges that will interfere with piston and ring travel. Most projections can be removed by handstoning, using a fine stone. Figure 3-4 shows a liner before and after the ports were stoned.

EXCESSIVELY WORN LINERS

Over a period of time, cylinder liners become worn simply because of engine operation. The best method of finding excessive wear is to take measurements of the cylinder liner with an inside micrometer caliper. Two

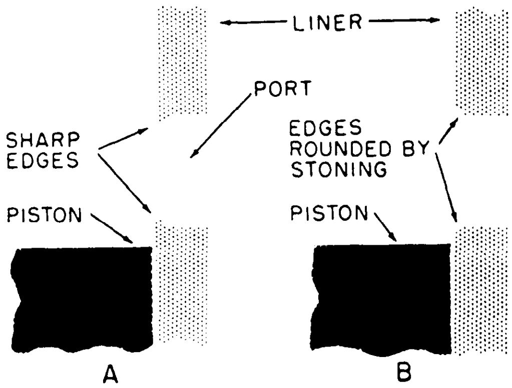

Figure 3-4.–Liner before and after stoning.

types of liner wear check are illustrated in figure 3-5. Excessive maximum diameter results from general wear equally around the cylinder. Out-of-roundness is produced by the piston thrusting against one or two sides of the cylinders.

Clearance between a piston and a liner is generally checked by measuring both parts with a micrometer. On smaller engines, you can use a feeler gauge. Clearance in excess of that specified by the manufacturer is generally due to liner wear, which normally is greater than piston wear.

To determine liner wear, take measurements at three levels in the liner. Take the first measurement slightly below the highest point to which the top ring travels; take the next measurement slightly above the lowest point of compression ring travel; and take the third measurement at a point about midway between the first two. (Record all readings, so that rapid wear of any particular cylinder liner will be evident.) If wear or out-of-roundness exists beyond specified limits, replace the liner. Figure 3-6 shows two examples of taking

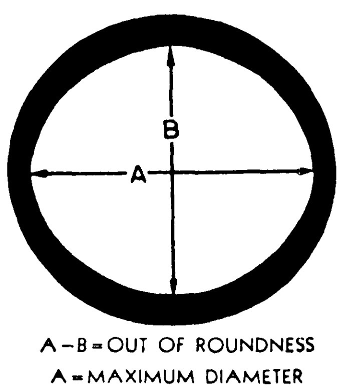

Figure 3-5.–Measurements for determining liner wear.

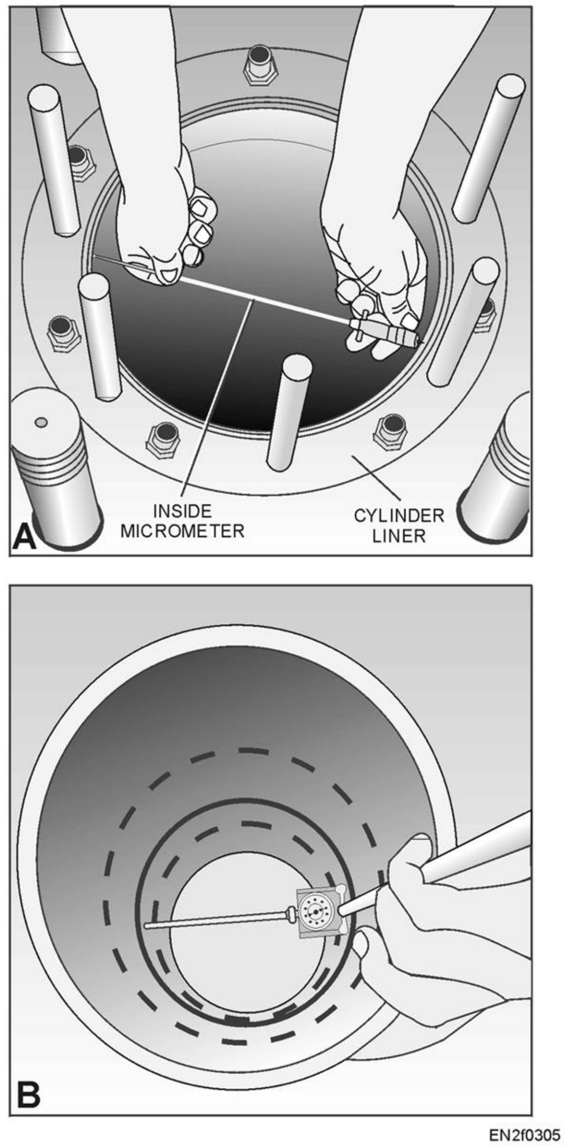

Figure 3-6.–Measuring the inside of a cylinder liner.

inside measurements. The liner shown in figure 3-6, view B, requires at least twice as many measurements as other types of liners because it is from an opposed piston.

You will not get accurate measurements unless you position the caliper or gauge properly in the liner. Common errors in positioning are illustrated in views A and B of figure 3-7. Hold one end of the caliper firmly against the liner wall as shown in view A of figure 3-6. Then move the free end back and forth, and up and down, until you establish the true diameter of the liner. The moving end will trace a patch similar to that illustrated in figure 3-8.

Considerable experience in using an inside micrometer or cylinder gauge is necessary to ensure accuracy. As a precaution against error, it is a good

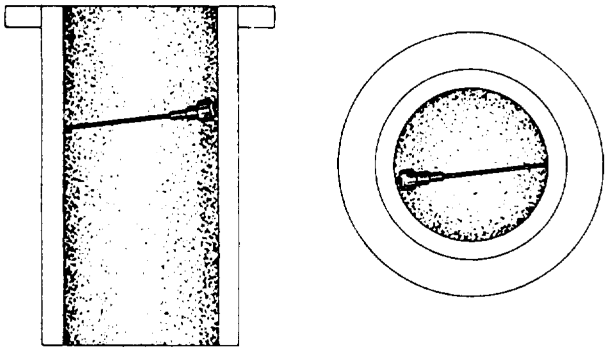

Figure 3-7.—Errors to avoid when taking liner measurements.

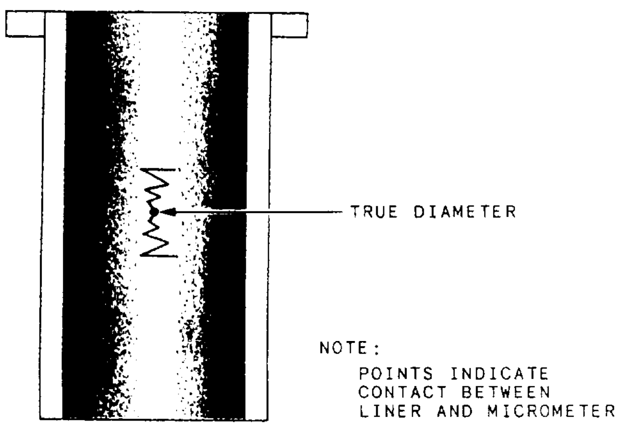

Figure 3-8.—Trace of caliper end when determining the true diameter of a liner.

practice for two persons to take the liner measurement; then any discrepancy between the two sets of readings can be rechecked.

Causes

Excessive or abnormal wear of cylinder liners may be caused by insufficient lubrication, dirt, improper starting procedures, or low cooling water temperature.

The lubricating system must be carefully maintained in proper working order. The method of cylinder liner lubrication varies with different engines. The proper grade of oil, according to engine specifications, should be used

The engine must not be operated in a dirty condition. The air box, crankcase, and manifold should be cleaned and maintained in a clean condition, to avoid cylinder wear and scoring. (Attention to the air cleaner, oil filters, and oil centrifuge are the best precautions against the entrance of dirt into the engine.)

Improper starting procedures will cause excessive wear on the liners and pistons. When an engine is first started, some time may elapse before the flow of lubricating oil is completed; also, the parts are cold and condensation of corrosive vapors is accelerated accordingly. These two factors (lack of lubrication and condensation of corrosive vapors) make the period immediately after starting a critical time for cylinder liners. If an independently driven oil pump is installed, it must be used to prime the lube oil system and build up oil pressure before the engine is started The engine should not be subjected to high load during the warm-up period. Follow the manufacturer's instruction manual concerning warm-up time and load application for the engine concerned

The cooling water of an engine should always be maintained within the specified temperature ranges. If the temperature is allowed to drop too low, corrosive vapors will condense on the liner walls.

Repairs

Cylinder liners worn beyond the maximum allowable limit should be replaced. You will find the maximum allowable wear limits for engines in the appropriate manufacturer's technical manual or the Diesel Engine Wear Limit Chart available from the Naval Sea Systems Command. In the absence of such specific information, the following wear limits (established by NAVSEA) apply in general to

1. two-stroke cycle engines with aluminum pistons: 0.0025 inch per inch diameter,

2. slow-speed engines over l8-inch bore: 0.005 inch per inch diameter, and

3. all other engines: 0.003 inch per inch diameter.

If you must remove a liner, follow the instructions given on the appropriate maintenance requirement card (MRC) or in the manufacturer's technical manual for the particular type of engine. Figure 3-9 illustrates the method generally used to remove a cylinder liner.

To remove the cylinder liner, proceed as follows:

1. Drain the water from the engine.

2. Remove the cylinder head.

3. Remove the piston(s).

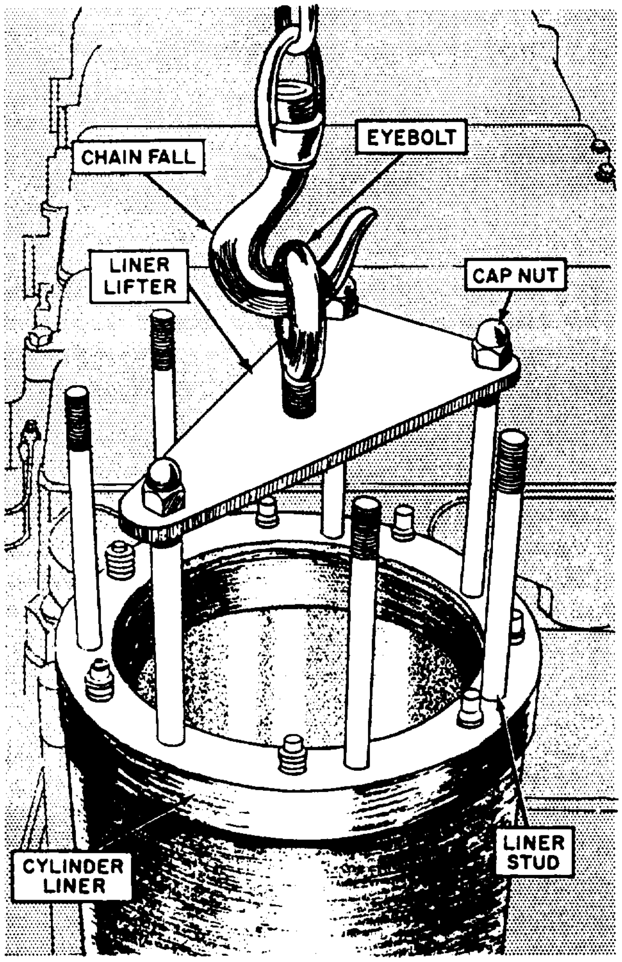

Figure 3-9.—Removing a cylinder liner.

4. Attach the special liner puller to the liner studs and tighten the nuts by hand. (The nuts must be hand tightened; if a wrench is used, the threads on both the nuts and the studs may be damaged.)

5. Attach the hook of the chain fall and pull slightly until the liner breaks free (fig. 3-9). If the liner fails to break loose immediately, apply pressure at the bottom of the liner. To do this, place a block of wood on the crankshaft throw, and force it up against the liner by rotating the turning gear.

6. Lift the liner up until it clears the top of the engine block and remove it to a safe place. You may need to rotate the liner slightly while removing it from the engine block.

INSPECTING, TESTING, AND REPAIRING CYLINDER HEADS

Conditions requiring repair of a cylinder head are similar to those for cylinder liners and can be grouped under cracks, corrosion, distortion, and fouling.

CRACKS

The symptoms of a cracked cylinder head are the same as those of a cracked liner. Cracks in cylinder heads are best located by either visual inspection or magnetic powder inspection. On some types of engines, a defective cylinder can be located by bringing the piston of each cylinder, in turn, to top dead center and applying compressed air. When air is applied to a damaged cylinder, a bubbling sound indicates leakage.

When the cylinder head is removed from the engine, it can be checked for cracks by the hydrostatic test used on cylinder liners equipped with integral cooling passages.

Cracks generally occur in cylinder heads on the narrow metal sections between such parts as valves and injectors. The cracks may be caused by adding cold water to a hot engine, by restricted cooling passages, by obstructions in the combustion space, or by improper tightening of studs.

Aboard ship, cracked cylinder heads usually must be replaced. It is possible to repair them by welding, but this process requires special equipment and highly skilled personnel normally found only at repair activities.

CORROSION

Burning and corrosion of the mating surfaces of a cylinder head may be caused by a defective gasket. Although regular planned maintenance ordinarily prevents this type of trouble, burning and corrosion may still take place under certain conditions. When corrosion and burning occur, there may be a loss of power due to combustion gas leakage out of or water leakage into the combustion space. Other symptoms of leakage may be (1) hissing or sizzling in the head where gases or water may be leaking between the cylinder head and the block, (2) bubbles in the cooling water expansion tank sight glass, or (3) overflow of the expansion tank.

Gaskets and grommets that seal combustion spaces and water passages must be in good condition; otherwise the fluids will leak and cause corrosion or burning of the area contacted. Improper cooling water treatment may also accelerate the rate of corrosion.

In general, cylinder heads that are burned or corroded by gas or water leakage are so damaged that they must be replaced.

DISTORTION

Warpage or distortion of cylinder heads becomes apparent when the mating surfaces of the head and block fail to match properly. If distortion is severe, the head will not lit over the studs. Distortion may be caused by improper welding of cracks or by improper tightening of the cylinder head studs. Occasionally, new heads may be warped because of improper casting or machining processes.

Repair of distorted or damaged cylinder heads is often impracticable. They should be replaced as soon as possible and turned in to the nearest supply activity, which will determine the extent of damage and the method of repair.

FOULING

If the combustion chambers become fouled, the efficiency of combustion will decrease. Combustion chambers are designed to create the desired turbulence for mixing the fuel and air; any accumulation of carbon deposits in the space will impair both turbulence and combustion by altering the shape and decreasing the volume of the combustion chamber.

Symptoms of fouling in the combustion chambers are smoky exhaust, loss of power, or high compression. Such symptoms may indicate the existence of extensive carbon formation or clogged passages. In some engines, these symptoms indicate that the shutoff valves for the auxiliary combustion chambers are stuck

Combustion chambers may also become fouled because of faulty injection equipment, improper assembly procedures, or excessive oil pumping.

Cleaning of fouled combustion spaces generally involves removing the carbon accumulation. The best method is to soak the dirty parts in an approved solvent and then wipe off all traces of carbon. You may use a scraper to remove carbon, but be careful to avoid damaging the surfaces. If oil pumping is the cause of carbon formation, check the wear of the rings, bearings, pistons, and liners. Replace or recondition excessively worn parts. Carbon formation resulting from improperly assembled parts can be avoided by following procedures described in the manufacturer’s technical manual.

INSPECTING, TESTING, AND REPAIRING VALVES AND VALVE ASSEMBLIES

Regardless of differences existing in engine construction, there are certain troubles common to all assemblies.

STICKING VALVES

Sticking valves will produce unusual noise at the cam followers, pushrods, and rocker arms and may cause the engine to misfire. Sticking is usually caused by resinous deposits left by improper lube oil or fuel.

To free sticking valves without having to disassemble the engine, use one of several approved commercial solvents. If the engine is disassembled, use either a commercial solvent or a mixture of half lube oil and half kerosene to remove the resins. Do NOT use the kerosene mixture on an assembled engine, since a small amount of this mixture settling in a cylinder could cause a serious explosion.

BENT VALVES

Bent or slightly warped valves tend to hang open. A valve that hangs open not only prevents the cylinder from firing, but also is likely to be struck by the piston and bent so that it cannot seat properly. Symptoms of warped or slightly bent valves will usually show up as damage to the surface of the valve head. To lessen the possibility that cylinder head valves will be bent or damaged during overhaul, NEVER place a cylinder head directly on a steel deck or grating; use a protective material such as wood or cardboard. Also, NEVER pry a valve open with a screwdriver or similar tool.

WEAK SPRINGS

Valves may close slowly, or fail to close completely, because of weak springs. At high speeds, valves may “float,” thus reducing engine efficiency. Valve springs wear quickly when exposed to excessive temperatures and to corrosion from moisture combining with sulfur present in the fuel.

BURNED VALVES

Burned valves are indicated by irregular exhaust gas temperatures and sometimes by excessive noise. In general, the principal causes of burned valves are carbon deposits, insufficient tappet clearance, defective valve seats, and valve heads that have been excessively reground.

The principal cause of burned exhaust valves is small particles of carbon that lodge between the valve head and the valve seat. These particles come from incomplete combustion of the fuel or oil left by the piston rings in the cylinder. The particles hold the valve open just enough to prevent the valve head from touching the valve seat. The valve is cooled by several means, including its contact with the valve seat. When carbon particles prevent contact, the heat normally transferred from the valve head to the seat remains in the valve head. The valve seat seldom burns because the water jackets surrounding the seat usually provide enough cooling to keep its temperature below a dangerous point.

When cleaning carbon from cylinder heads, remove all loose particles from the crevices; be extremely careful that you do not nick or scratch the valve or seat. Removing the valves from the engine will make it easier to clean the passages and remove the carbon deposits from the underside of the valve heads.

Check the tappet clearance adjustments at frequent intervals to be certain they are correct and that the locking devices are secure. The adjustment of valve clearances is discussed later in this chapter.

Most engines are equipped with valve seat inserts made of hard, heat-resisting, alloy steel. Occasionally, a seat will crack and allow the hot gases to leak, burning both the insert and the valve. Sometimes a poor contact between the valve seat insert and the counterbore prevents the heat from being conducted away, and the high temperatures deform the insert. When this occurs, both the seat and the valve will burn; the seat insert must be rep1aced.

LOOSE VALVE SEATS

You can avoid causing loose valve seats only by installing them properly. Clean the counterbore thoroughly to remove all carbon before shrinking in an insert. Chill the valve seat with dry ice and place the cylinder head in boiling water for approximately 30 minutes; then drive the insert into the counterbore with a valve insert installing tool, as illustrated in figure 3-10. Never strike a valve seat directly. Do the driving operation quickly, before the insert reaches the temperature of the cylinder head

When replacing a damaged valve with a new one, inspect the valve guides for excessive wear. If the valve moves from side to side as it seats, replace the guides.

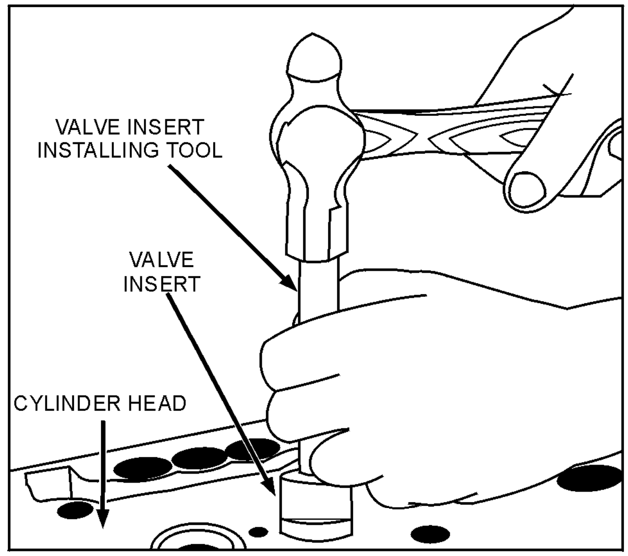

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Figure 3-10.–Driving a valve iusert into the cylinder head counterbore.

PITTING

If the valve seat is secured firmly in the counterbore and is free of cracks and burns, you may remove slight damage such as pitting by hand grinding (fig. 3-11). Generally, you will use prussian blue to check the valve and valve seat, but if this is not available, use any thin dark oil-based paint. Allow the valve to seat by dropping it on the valve seat from a short distance. If the surfaces fail to make complete contact, regrinding is necessary.

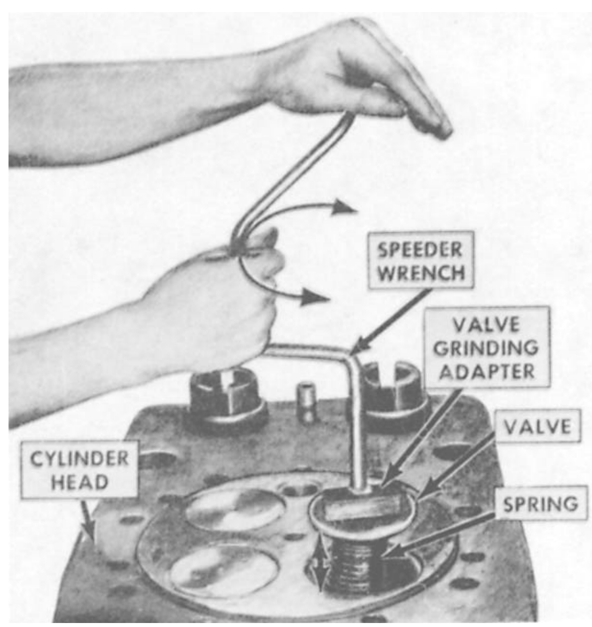

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Figure 3-11.–Hand grinding a valve and valve seat.

In any valve reconditioning job, the valve seat must be concentric with the valve guide. You can determine the concentricity with a dial indicator, as shown in figure 3-12.

If you must grind a valve seat, hold hand grinding to a minimum and never use it in place of machine grinding, in which a grinding stone is used to refinish the seat (fig. 3-13). Grind the seat a few seconds at a time until it is free of pits. Check the seat after each cut.

The primary objection to hand grinding the valve to the seat is that a groove or indentation may be formed in the valve face. Since the grinding is done when the valve is cold, the position of the groove with respect to the seat is displaced as the valve expands slightly when the engine is running. This condition is illustrated (greatly exaggerated) in figure 3-14. Note that when the valve is hot, its ground surface does not make contact at all with the ground surface of the seat. Therefore, hand grinding should be used only to remove slight pitting or as the final and finishing operation in a valve reconditioning job.

Some valves and seat are not pitted sufficiently to require replacement but are pitted to such an extent that hand grinding would be unsatisfactory. Such valves may be refaced on a lathe (fig. 3-15), and the valve seats may be reseated by power grinding equipment (fig. 3-13).

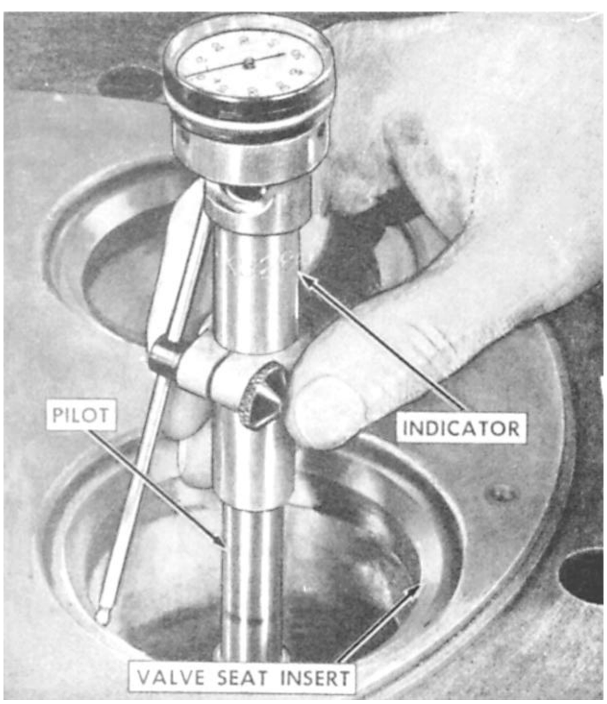

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Figure 3-12.—Determining concentricity of the valve seat with a dial indicator.

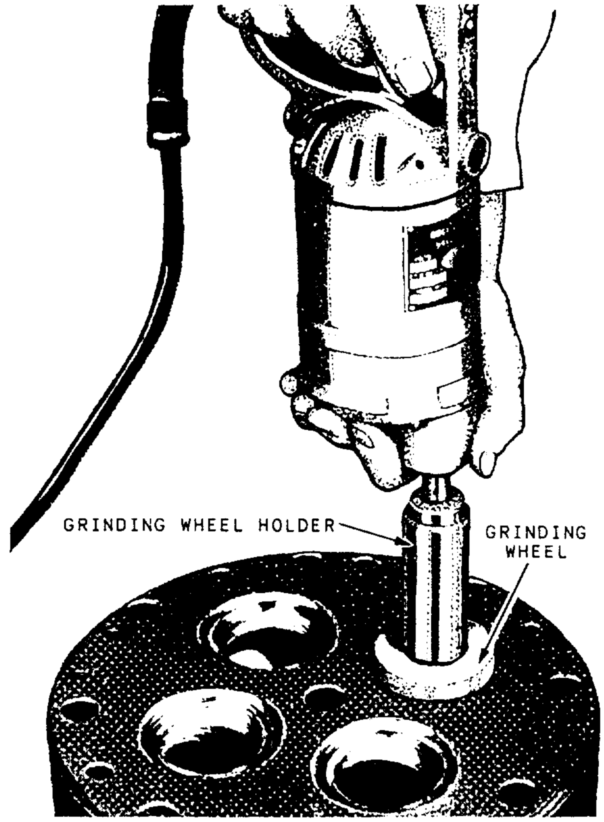

Figure 3-13.—Machine grinding a valve seat.

Normally, these operations are done at a repair base or naval shipyard.

A valve head that is excessively reground to such an extent that its edge is sharp, or almost sharp, will soon burn. A sharp edge cannot conduct the heat away fast enough to prevent burning. This is the factor that limits the extent to which a valve may be refaced.

BROKEN VALVE SPRINGS

Broken valve springs cause excessive valve noise and may cause erratic exhaust gas temperatures. The actual breaking of the valve springs is not always the most serious consequence. Actions following the breaking cause the most serious damage to the engine. When a spring breaks, it may collapse just enough to allow the valve to drop into the cylinder, where it may be struck by the piston. In addition, the valve stem locks or keepers may release the valve and allow it to drop into the cylinder, causing severe damage to the piston, cylinder head, and other nearby parts.

You can take a number of precautions to prevent or minimize corrosion and metal fatigue, which cause valve springs to break Be reasonably careful when you

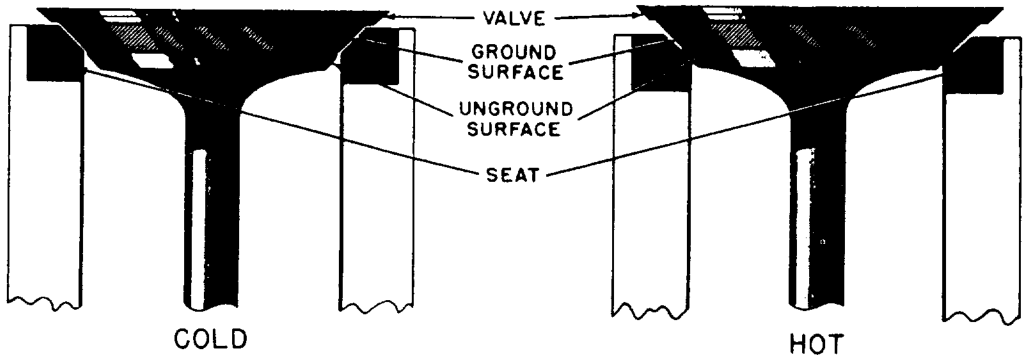

Figure 3-14.—Excessively band-ground valve.

assemble and disassemble a valve assembly. Before you reassemble a valve assembly, be sure to thoroughly clean and inspect the valve spring. (Use kerosene or diesel fuel for cleaning. NEVER use an alkaline solution; it will remove the protective coating.) The condition of the surface of a valve spring is the best indication of impending failure. (Use magnafluxing to help find cracks that would otherwise be invisible.)

The free length of a valve spring should be within the limits specified in the manufacturer's technical manual. If such information is not available, compare the length of a new spring with that of the used spring. If the length of the used spring is more than 3 percent shorter than that of the new spring, replace the used spring immediately. Remember, however, that loss of spring tension will NOT always show up as a loss in overall length. Springs may be the proper length, but they may have lost enough tension to warrant replacement.

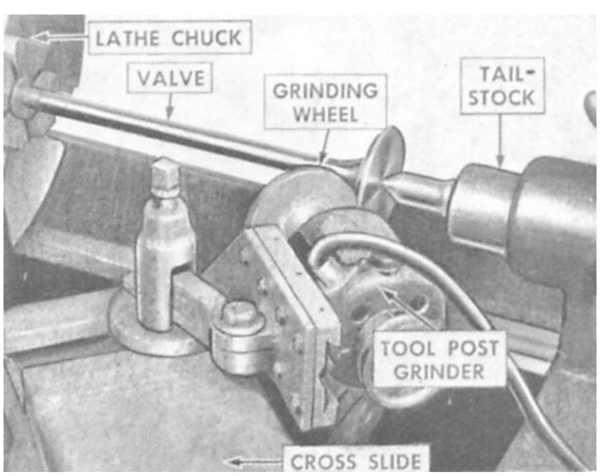

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Figure 3-15.—Facing a valve on a lathe.

Do not reinstall springs with nicks, cracks, or surface corrosion. Replace them. To minimize corrosive conditions, use clean lube oil, eliminate water leaks, and keep vents open and clean

WORN VALVE KEEPERS AND RETAINING WASHERS

Worn valve keepers and retaining washers may result if valve stem caps (used in some engines) are improperly fitted Caps are provided to protect and increase the service life of the valve stems. Trouble occurs when the cap does not bear directly on the end of the stem, but bears instead on the valve stem lock or the spring retaining washer. This transmits the actuating force from the cap to the lock or the retaining washer, and then to the stem, causing excessive wear on the stem groove and the valve stem lock As a result, the retaining washer wiIl loosen and the valve stem may break

An improper fit of a valve stem cap may be due to the use of improper parts or the omission of spacer shims. Steel spacer shims, required in some caps to provide proper clearance, are placed between the end of the valve stem and the cap; leaving out the shims will cause the shoulder of the cap to come in contact with the lock. When you disassemble a valve assembly, determine whether or not shims are used. If shims are used, record their location and exact thickness. Valve caps must be of the proper size, or troubles similar to those resulting from shim omission will occur. Never attempt to use caps or any other valve assembly parts that are worn.

BROKEN VALVE HEADS

Broken valve heads usually cause damage to the piston, liner, cylinder head, and other associated parts. This damage is generally repairable only by replacement of these parts.

Whether the causes of broken valve heads are mechanical deformation or metal fatigue, you must take every precaution to prevent their occurrence. If a valve head breaks loose, be sure to make a thorough inspection of all associated parts before you replace the valve.

ROCKER ARMS AND PUSHRODS

The principal trouble that rocker arms and pushrods may have is WEAR, which may occur in bushings, or on the pads, end fittings, or tappet adjusting screws.

Worn rocker arm bushings are usually caused by lubricating oil problems. A bushing with excessive wear must be replaced. When installing a new bushing, you usually need to use a reamer for the final fit.

Wear at the points of contact on a rocker arm is generally in the form of pitted, deformed, or scored surfaces. Wear on the rocker arm pads and end fittings is greatly accelerated if lubrication is insufficient or if there is excessive tappet clearance. Pushrods are usually positioned to the cam followers and rocker arms by end fittings. The pads are the rocker arm ends that bear the valve stem or valve stem cap. When the tappet clearance is excessive, the rods shift around, greatly increasing the rate of wear of both the rocker arm and the rod contact surfaces. Worn fittings necessitate the replacement of parts. Continued use of a poor fitting and worn pushrod is likely to result in further damage to the engine, especially if the rod should come loose.

Worn tappet adjusting screws and locknuts usually make maintaining proper clearances and keeping the locknuts tight very difficult. Wear of the adjusting screws is usually caused by loose locknuts, which allow the adjusting screw to work up and down on the threads each time the valve is opened and closed. To prevent this wear, tighten the locknuts after each adjustment and check the tightness at frequent intervals.

If the threads are worn, replace the entire rocker arm. Do NOT attempt to repair the threads or to use a new tappet adjusting screw except in cases of emergency.

The adjustment of the rocker arm assembly consists chiefly of adjusting the tappets for proper running clearance. The valve clearance for both intake and exhaust valves should be readjusted after overhaul. The procedure for adjusting the rocker arm tappets of a typical 4-stroke cycle engine is as follows:

1. Rotate the crankshaft and move the piston whose tappets you plan to adjust to top dead center of the compression stroke.

2. Loosen the locknut (jam nut) on the tappet screw, and insert a screwdriver in the slot of the screw.

3. Insert a feeler gauge of the proper thickness between the tappet bearing and the end of the valve stem.

4. Tighten the tappet screw (fig. 3-16) until the feeler gauge will just slide freely between the bearing and the valve stem.

5. lighten the jam nut and check the clearance. The jam nut has a tendency to increase the clearance when tightened; therefore, ALWAYS check the clearance after you tighten the jam nut.

The procedure just outlined is a preliminary, or cold engine check. Check and readjust the clearance, if necessary, after the engine has been in operation for a short time and has reached the normal operating temperature. The manufacturer’s technical manual will give the recommended valve clearances for a specific make and model of engine and will indicate whether the clearances given apply to cold or hot engines.

CAM FOLLOWERS AND LASH ADJUSTERS

Regardless of the type of cam follower, wear is the most common trouble. Worn rollers will usually develop holes or pit marks in the roller surfaces. The mushroom type may develop a shallow channel when the cam

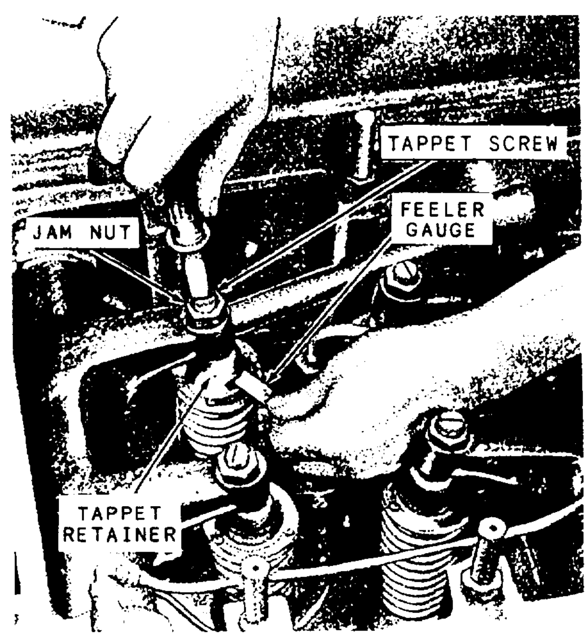

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Figure 3-16.—Adjusting valve clearance.

follower fails to revolve and the cams wipe the same surface each time the camshaft revolves.

Normal use will cause surface disintegration, usually as the hardened surfaces begin to fatigue. The condition is aggravated by abrasive particles. Nicks and dents on rollers will also cause disintegration.

You must make constant checks for defective rollers or surfaces and for nicks, scratches, or dents in the camshaft. Whenever you find a defective cam follower, you should replace it. In roller-type cam followers you must replace a worn cam follower body and guide or roller needle bearings (if used).

Defective or poorly operating valve adjusters allow clearance or lash in the valve gear. Noisy operation of a lash adjuster indicates that there is insufficient oil in the cylinder of the unit. When you discover a noisy lash adjuster and the oil supply or pressure is not the source of trouble, remove and disassemble the unit according to the manufacturer's instructions.

Since the parts of lash adjusters are not interchangeable, disassemble only one unit at a time. Check for resinous deposits, abrasive particles, a stuck ball check valve, a scored check valve seat, and excessive leakage. Carefully wash all parts of the hydraulic lash adjuster in kerosene or diesel fuel. Check such parts as the cam follower body, plunger or piston, and hydraulic cylinder for proper fit.

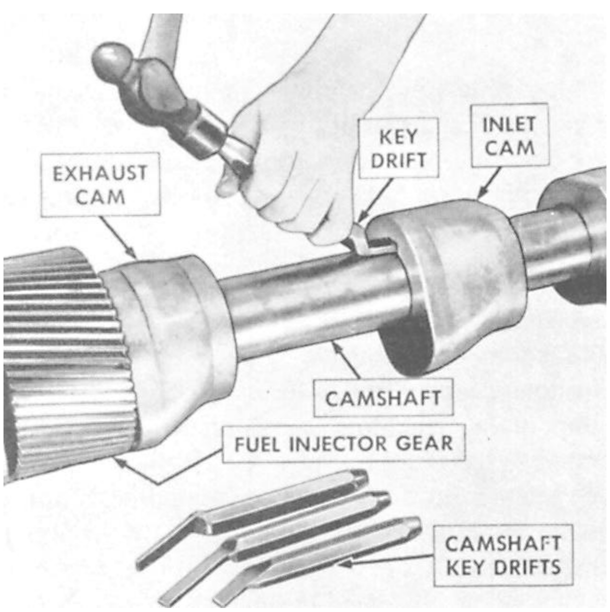

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Figure 3-17.—Removing an individual cam.

INSPECTING AND REPAIRING CAMSHAFTS

Camshafts can be saved when the cams alone are damaged, if the cams are of the individual type, since such cams may be removed and replaced. Figure 3-17 illustrates the method of removing an individual cam from its shaft.

When you remove a camshaft from an engine, clean it thoroughly with either kerosene or diesel fuel. After cleaning the shaft, dry it with compressed air. After cleaning the cam and journal surfaces, inspect them for any signs of scoring, pitting, or other damage.

When you remove or insert a camshaft through the end of the camshaft recess, rotate it slightly. Rotating the camshaft allows it to enter easily and reduces the possibility of damage to the cam lobes and bearings.

After you visually inspect a camshaft, place it on V-blocks and measure the shaft runout by using a dial indicator. When you measure the runout, take the out-of-roundness into consideration. Compare your measurements to the manufacturer's specifications. Also, measure the camshaft bearing journals with a micrometer. Figure 3-18 illustrates a camshaft with bearing journals.

A camshaft needs to be replaced if the following conditions occur:

1. The lobes are damaged, as lobes cannot be repaired.

2. Runout exceeds the manufacturer's specifications.

3. Wear on the shaft bearing journals exceeds the manufacturer's specifications.

4. The keyways are damaged.

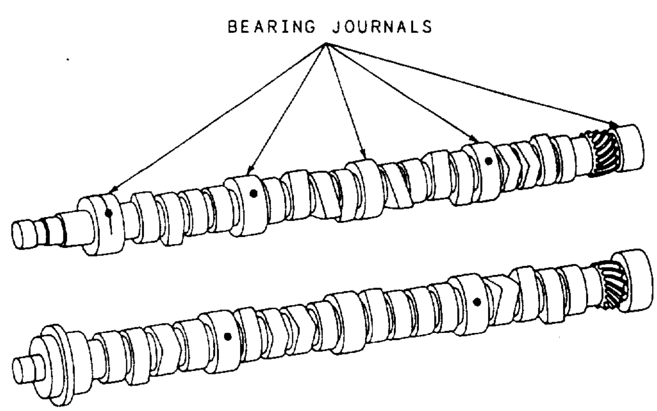


Figure 3-18.—Camshaft with bearing journals in a V-type engine.

Before you reinstall a good camshaft, remove the minor surface defects on the cams and the camshaft by using crocus cloth or a fine stone.

INSPECTING, MAINTAINING, AND REPLACING PISTON RINGS AND PISTONS

The following paragraphs are general procedures for inspections, maintenance, and replacement of piston rings and pistons. You must consult the manufacturer's technical manual for specific instructions.

PISTON RINGS

Over a period of time all piston rings wear. Some stick and may even break. While you may be able to free stuck rings and make them serviceable, you must replace excessively worn or broken rings with new ones. The installation of a new set of rings in an engine requires great care. Most of the damage that is done occurs when the rings are being placed in the grooves of a piston or when the piston is being inserted into the cylinder bore.

Be very careful when you remove the piston and connecting rod from the cylinder. In most engines, you should not remove a piston from a cylinder until you have scraped the cylinder surface above the ring travel area. In addition to removing all carbon, you must remove any appreciable ridge before removing the piston. Do not remove a ridge by grinding, as this will allow small abrasive particles from the stone to enter the engine. Use a metal scraper and place a cloth in the cylinder to catch all metal cuttings. You can usually scrape enough from the lip of a cylinder to allow the piston assembly to slide out of the liner. After removing the piston, you can make a more detailed inspection of the ridge.

Finish scraping the remaining ridge, but be careful not to go too deep. Finish the surface with a handstone. For large ridges, you may need to remove the liner and use a small power grinder.

With the piston and connecting rod removed, check the condition and wear of the piston pin bushing, both in the piston and in the connecting rod.

The best way to remove and install piston rings is with a tool similar to that shown in figure 3-19. These tools generally have a device that limits the amount the ring can be spread and prevents the rings from being deformed or broken.

A ring that is securely stuck in the groove will require additional work. You may need to soak the piston

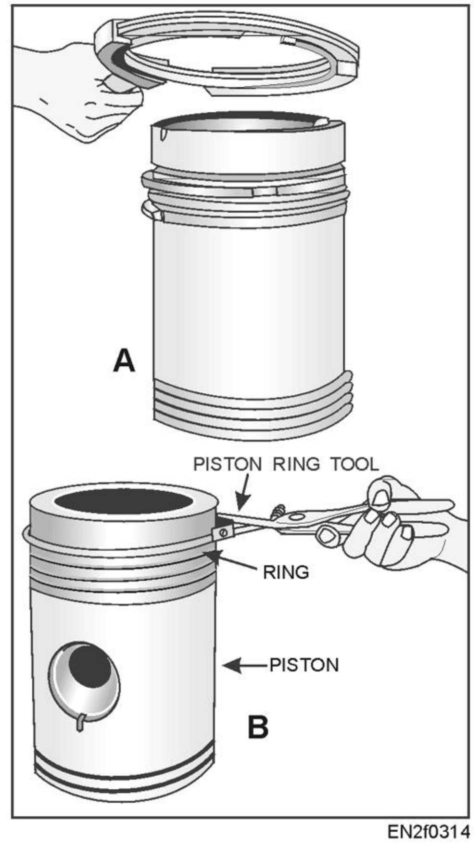


Figure 3-19.–Piston ring tools used for removal or installation.

overnight in an approved cleaning solvent or in diesel oil. If soaking does not free the ring, you must drive it out with a brass drift. The end of the drift should be shaped and ground to permit its use without damage to the lands.

After removing the rings, thoroughly clean the piston with special attention to the ring grooves. (Diesel oil or kerosene are satisfactory cleaning agents.) In addition, you may need to clean excessive deposits from the oil return holes in the bottom of the oil control ring grooves with a twist drill of a diameter corresponding to the original size of the holes.

Make another complete inspection after cleaning the piston. Check all parts for any defects that could require replacement of the piston. Give particular attention to the ring grooves, especially if the pistons have been in service for a long period of time. A certain amount of enlargement of the width of the grooves is normal, and SHOULDERING of the groove may occur. Shouldering, as illustrated in figure 3-20, results from the "hammering out" motion of the rings. The radial depth of thickness of the ring is much less than the groove depth, and while the ring wears away an amount of metal corresponding to its own width, the metal at the bottom of the groove remains unchanged. Shouldering

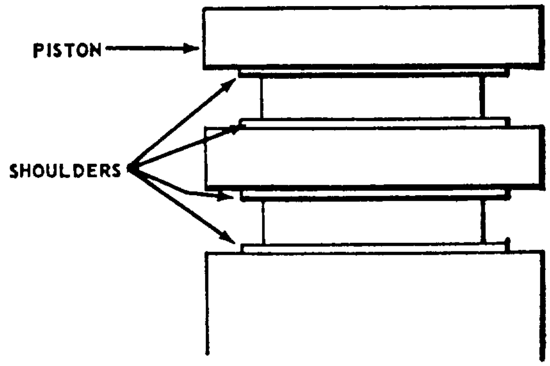


Figure 3-20.—Ring groove shoulders due to wear.

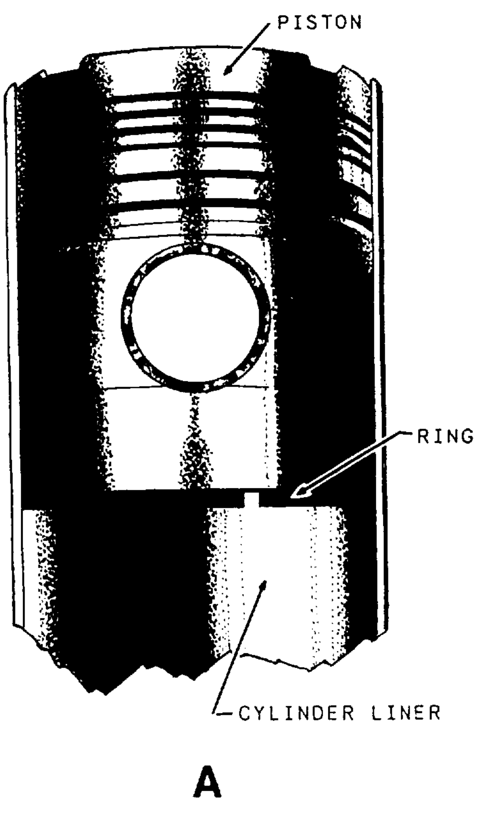
usually requires replacement of the piston since the shoulders prevent the proper fitting of new rings.

After determining that a piston is serviceable, inspect the rings carefully todetermine whether they can be reused. If they do not meet specifications, you must install new rings.

When installing rings, measure the gap with a feeler gauge. To measure the gap, place the new rings inside the cylinder liner (fig. 3-21, view A) or in a ring gauge. When the gap is measured with the ring in the liner (fig. 3-21, view B), two measurements are necessary—one just below the upper limit of ring travel, and the other within the lower limit of travel. These measurements are necessary because the liner may have a slight amount of taper caused by wear. The ring gap must be within the limits specified in the manufacturer's technical manual. If the gap of a new ring is less than specified, file the ends of the ring with a straight-cut mill file to obtain the proper gap. If the gap is more than specified, install oversized rings.

To measure the ring gap of used rings, hold the rings in place on the piston with a ring compressing tool (fig. 3-22). But before you measure the ring gap with the ring on the piston, first measure the piston for wear and out-of-roundness.

After ensuring the proper gap clearance, you can reinstall the piston pin and connecting rod. During reassembly and installation of a piston and connecting rod assembly, be sure that all parts are well lubricated. Install the rings on the piston with tools similar to those used for ring removal. When installing piston rings, spread them as little as possible to avoid breaking the rings. Insert the lowest ring first. When all the rings have



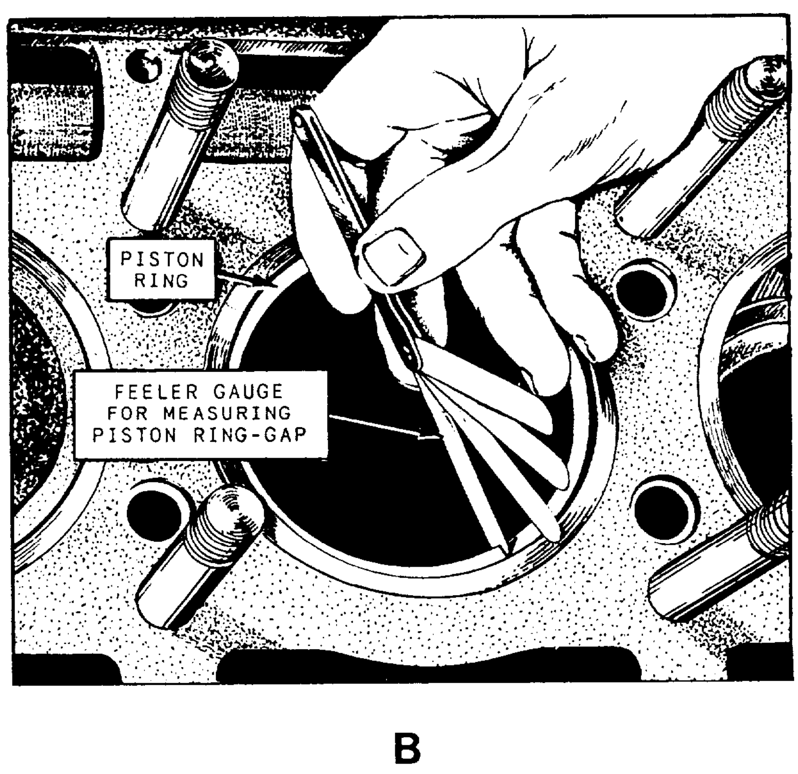


Figure 3-21.–A. Leveling a piston ring. B. Measuring ring gap clearance in a cylinder bore.

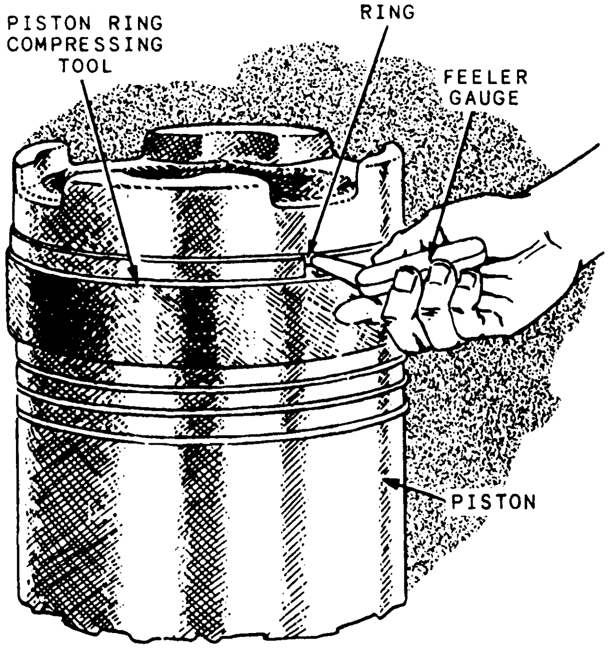


Figure 3-22.–Checking ring gap clearance.

been installed, check the ring-to-land clearance. (See fig. 3-23.) If the clearance is too small, the ring may bind or seize, allowing improper sealing and blowby to occur. If the clearance is excessive, the ring may flutter and break itself or the piston land.

After you have properly installed all the rings, coat the entire assembly with oil, then insert it into the cylinder bore. Position the rings so the gap of each successive ring is on an alternate side and the gaps are in line with the piston pin bosses. On large engines, use a chain fall to hold the piston assembly in position as you lower it into the cylinder. (See fig. 3-24.)

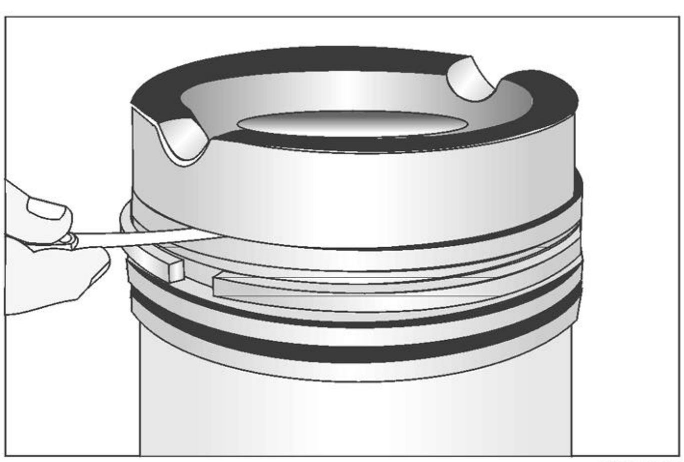


Figure 3-23.–Checking ring groove side clearance.

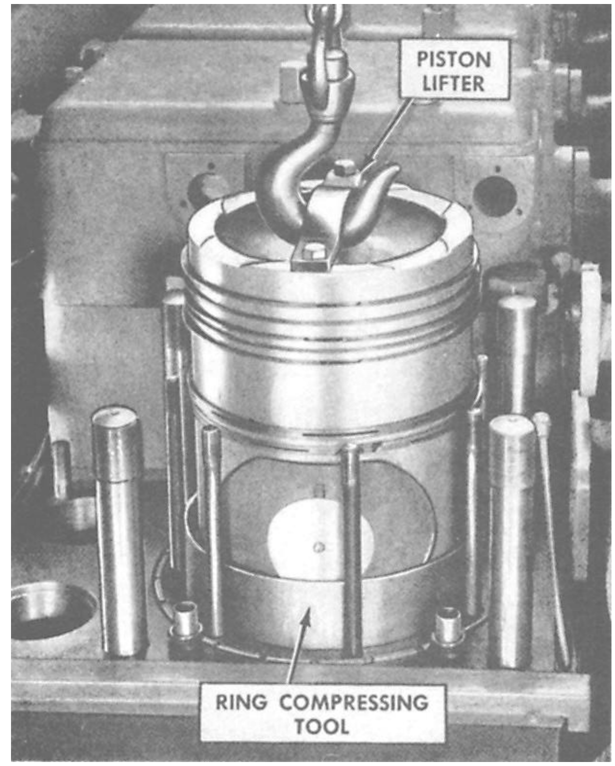


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Figure 3-24.–Installing a piston in a cylinder bore with a funnel-type ring compressor.

When a piston is being inserted into a cylinder, the piston rings must be compressed evenly. Special funnel-type tools, similar to the one shown in figure 3-24 are usually provided for this purpose. Another type of ring compressing tool is a steel band that can be placed around the ring and tightened.

PISTONS

Trunk-type pistons are subject to forces such as gas pressure, side thrust, inertia, and friction. These forces, together with overheating and the presence of foreign matter, may cause troubles such as undue piston wear, crown and land dragging, cracks, piston seizure, clogged oil holes, and piston pin bushing wear.

Excessive Piston-to-Liner Clearance

Symptoms of excessive clearance between a piston and its cylinder are piston slap and excessive oil consumption. Piston slap occurs just after top dead center and bottom dead center, as the piston shifts its thrust from one side to the other. As the cylinder taper increases with wear, oil consumption increases. Since taper causes the rings to flex on each stroke of the piston, excess ring wear occurs, allowing lube oil to pass and be burned in the cylinder. This results in the accumulation of excessive carbon deposits.

Crown and Land Dragging

Pistons and liners may become sufficiently worn to permit the piston to cock over in the cylinder. This allows the crown and ring lands to drag on the cylinder wall. The results of dragging can be determined by visually inspecting the parts of the piston in question.

Piston Wear

Although piston wear is normal in all engines, the amount and rate of piston wear depend on several controllable factors. (The causes of excessive piston wear, and crown and land dragging, are also the causes of other piston troubles.)

One of the controllable factors is LUBRICATION. An adequate supply of oil is essential to provide the film necessary to cushion the piston and other parts within the cylinder and prevent metal-to-metal contact. Inadequate lubrication will not only cause piston wear and crown and land dragging, but also may cause piston seizure, and piston pin busing wear.

Lack of lubrication is caused either by a lack of lube oil pressure or by restricted oil passages. The pressure-recording instruments usually give warning of low oil pressure before any great harm results. However, clogged passages offer no such warnings, and their discovery depends on the care that is exercised in inspecting and cleaning the piston and connecting rod assembly.

Another controllable factor that may be directly or indirectly responsible for many piston troubles is IMPROPER COOLING WATER TEMPERATURE.

If an engine is not operated within the specified temperature limits, lubrication troubles will develop. High cylinder surface temperatures will reduce the viscosity of the oil. As the cylinder lubricant thins, it will run off the surfaces. The resulting lack of lubrication leads to excessive piston and liner wear. However, if temperatures are below those specified for operation, viscosity will be increased, and the oil will not readily reach the parts requiring lubrication.

Oil plays an important role in the cooling of the piston crown. If the oil flow to the underside of the crown is restricted, deposits caused by oxidation of the oil will accumulate, lowering the rate of heat transfer. Therefore, the underside of the piston crown should be thoroughly cleaned whenever pistons are removed

While insufficient and uneven cooling may cause ring land failure, excessive temperatures may cause piston seizure; an increase in the rates of oxidation of the oil, resulting in clogged oil passages; or damage to piston pin bushings.

Seizure or excessive wear of pistons may be caused by IMPROPER PIT. New pistons or liners must be installed with the piston-to-cylinder clearances specified in the manufacturer’s instruction manual.

PISTON PINS AND SLEEVE BEARINGS OR BUSHINGS

Every time you remove a piston assembly from an engine, inspect it for wear. Measure the piston pins and sleeve bearings or bushings with a micrometer, as shown in figure 3-25, to determine whether wear is excessive. Do NOT measure areas that do not make contact. Such areas include those between the connecting rod and piston bosses and areas under the oil holes and grooves.

You can press bushings out of the rod with a mandrel and an arbor press or with special tools, as shown in figure 3-26. You can also remove bushings by firt shrinking them with dry ice. Dry ice will also make it easier to insert the new bushing.

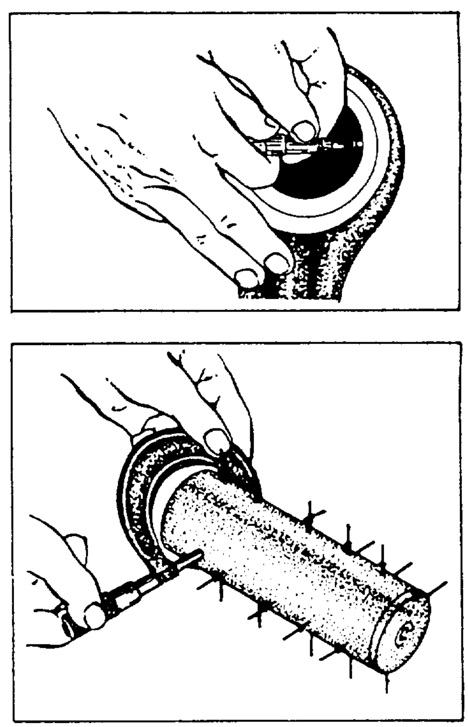

Figure 3-25.—Measuring a piston pin and piston bushing for wear.

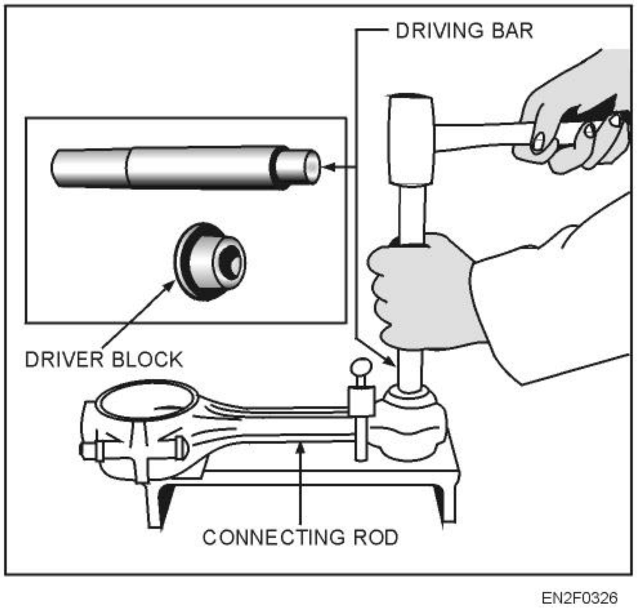

Figure 3-26.–Removing or installing a piston pin bushing.

When you insert new bushings, be sure that the bore into which they are pressed is clean and that the oil holes in the bushing and the oil passages in the rod are aligned. To obtain proper clearance, sometimes you will need to ream a piston pin bushing after it has been installed. Figure 3-27 shows equipment used to ream a bushing.

After installing a new bushing, check the alignment of the rod with equipment such as illustrated in figure 3-28. Be sure to check the manufacturer's technical manual for details concerning clearances and alignment procedures.

INSPECTING, MAINTAINING, AND REPAIRING CONNECTING RODS

Most connecting rod troubles involve either the connecting rod bearing or the piston pin bearing. You can avoid these troubles by performing proper maintenance procedures and by following instructions in the manufacturer's service manual. There are, however, certain unavoidable troubles, such as cracked connecting rods caused by defective material. Such cracks must be discovered before they develop to a point that the rod fails. Magniflux testing is considered the best method for locating cracks. If you discover a crack in a connecting rod, replace the rod; do not try to repair it. If you have to replace a damaged rod, send it, with other damaged parts, to a salvage center for possible reclamation.

Do not repair defective connecting rod bolts, except for removing small burrs by using a fine rectangular file. If you doubt the condition of a bolt or a nut, replace it.

Check the connecting rod bore for out-of-roundness with an inside micrometer. Make the correction and recheck the bore. If the distortion is permanent, replace the rod.

You can make plugged oil passages of connecting rods serviceable by running a wire through them. In extreme cases, you may need to drill the passages free of foreign matter.

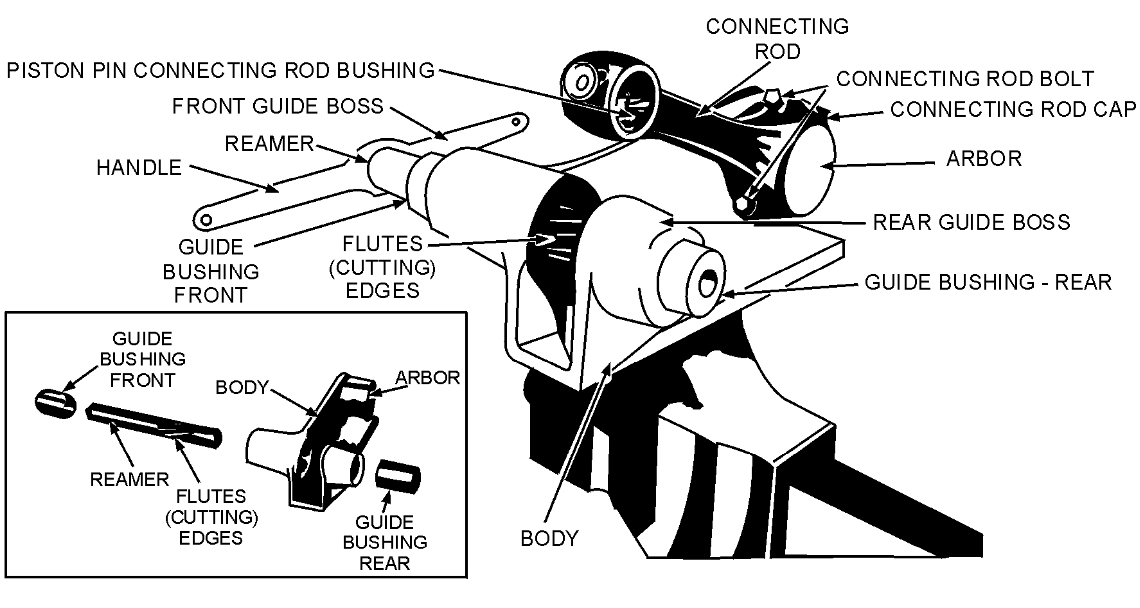

Figure 3-27.–Reaming equipment.

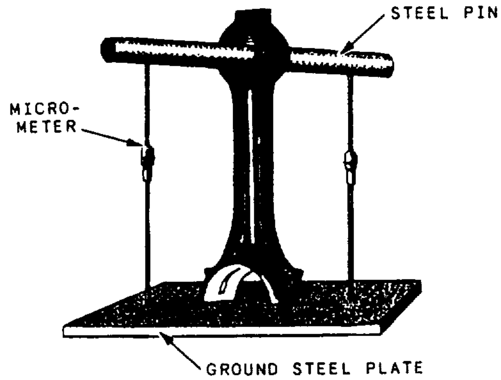

Figure 3-28.—Checking the alignment of a connecting rod.

REPAIRING CRANKSHAFTS AND JOURNAL BEARINGS

The repair of crankshafts and bearings varies depending on the extent of damage. There is no doubt about the necessity for replacing such items as broken or bent crankshafts. Out-of-round journals may be reground and undersize bearing shells may be installed, but this requires personnel skilled in the use of precision tools. If a new shaft is available, it should be installed and the damaged shaft should be sent to a salvage reclamation center. Under certain conditions, scored crankshaft journals or damaged journal bearings may be kept in service if proper repair is performed.

Repair of SCORED JOURNALS depends on the extent of scoring. If a crankshaft has been overheated, the effect of the original heat treatment will have been destroyed. In this case, the crankshaft should be replaced.

If journal scoring is only slight, you can use an oilstone for dressing purposes if you take precautionary measures with respect to abrasives during the procedure. During the dressing operation, plug all oil passages within the journal and those connecting the mainbearing journal and the adjacent connecting rod journal.

In the dressing procedure, use a fine oilstone, followed with crocus cloth, to polish the surface. After dressing journals, always wash them with diesel oil. This procedure must include washing the internal oil passages as well as the outside journal surfaces. Some passages are large enough to accommodate a cleaning brush; smaller passages can be cleaned by blowing them out with compressed air. Always dry the passages by blowing compressed air through them.

NEVER STOW A CRANKSHAFT OR BEARING PART ON ANY METAL SURFACE. When you remove a shaft from an engine, place it on a wooden plank with all journal surfaces protected. If the shaft is to be exposed for some time, protect each journal surface with a coating of heavy grease. Always place bearings on wooden boards or clean cloths.

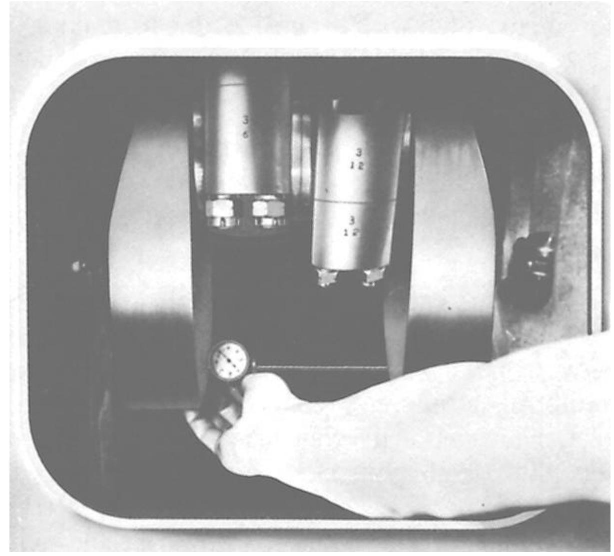

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Figure 3-29.—Using a strain or deflection gauge between crank webs.

CRANKSHAFT overhaul consists of an inspection, servicing for scoring and wear, and a determination of each crank web deflection. Take crank web deflection readings according to the Planned Maintenance System (PMS).

A strain gauge, often called a crank web deflection indicator, is used to take deflection readings. The gauge is merely a dial-reading inside micrometer used to measure the variation in the distance between adjacent crank webs as the engine shaft is barred over. Figure 3-29 shows a strain gauge between crank webs.

When you install the gauge, or indicator, between the webs of a crank throw, be sure to place the gauge as far as possible from the axis of the connecting rod journal. Rest the ends of the indicator in prick-punch marks in the crank webs. If these marks are not present, make them so that the indicator can be placed in its correct position. Consult the manufacturer’s technical manual for the proper location of new marks.

Readings are generally taken at the four crank positions: top dead center, inboard, near or at bottom dead center, and outboard. In some engines, it is possible to take readings at bottom dead center. In others, the connecting rod may interfere, making it necessary to take the reading as near as possible to bottom dead center without having the gauge come in contact with the connecting rod. When the gauge is in its lowest position, the dial will be upside down, making it necessary to use a mirror and flashlight to obtain a reading.

NOTE: Once you have placed the indicator in position for the first deflection reading, do not touch the gauge until you have taken and recorded all four readings.

Deflection readings are also used to determine correct alignment between the engine and the generator or between the engine and the coupling. However, when determining alignment, you should take a set of deflection readings at the crank nearest the generator or the coupling. In aligning an engine and generator, you may need to install new chocks between the generator and its base to bring the deflection within the allowable value. You may also need to shift the generator horizontally to obtain proper alignment. To align an engine and a coupling, first, correctly align the coupling with the drive shaft; then, properly align the engine to the coupling, rather than aligning the coupling to the engine.

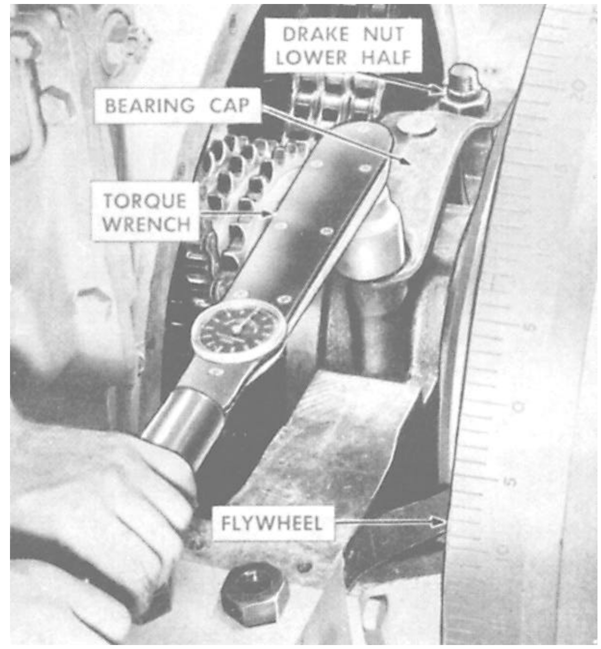
BEARING TROUBLES

Bearings become a continual source of trouble unless personnel entrusted with operating the engine follow the recommended operation and maintenance procedures exactly.

Severe bearing failures are indicated during engine operation by a pounding noise or by the presence of smoke in the vicinity of the crankcase. Impending failures may sometimes be identified by a rise in the lubricating oil temperature or a lowering of the lubricating oil pressure. Impending bearing failure may be detected during periodic maintenance checks or during engine overhauls by inspection of the bearing shells and backs for pits, grooves, scratches, or evidence of corrosion.

The indication of an impending failure does not necessarily mean that the bearing has completed its useful life. Journal bearings may perform satisfactorily with as much as 10 percent of the load-carrying area removed by fatigue failure. Other minor casualties may be repaired so that a bearing will give additional hours of satisfactory service.

Bearings should not be rejected or discarded for minor pits or minute scratches; however, areas indicating metallic contact between the bearing surface and the journal do mean replacement is needed. Use a bearing scraping tool to smooth minute pits and raised



5.9

Figure 3-30.—Using a torque wrench to tighten a main bearing.

surfaces. After working on bearings, make every effort to ensure that the bearing surfaces are clean. This also applies to the bearing back and the connecting rod journal Place a film of clean lubricating oil on the journals and the bearing surfaces before you reinstall them.

INSTALLING JOURNAL BEARINGS

Always check the markings of the lower and upper bearing halves so you install them correctly. Many bearings are interchangeable when new, but once they have become worn to tit a particular journal they must be reinstalled on that particular journal. You must mark or stamp each bearing half with its location (cylinder number) and the bearing position (upper or lower) to prevent incorrect installation.

You must also pull the connecting rod bearing cap nuts down evenly on the connecting rod bolts to prevent possible distortion of the lower bearing cap and consequent damage to the bearing shells, cap, and bolts. Use a torque wrench (fig. 3-30) to measure the torque applied to each bolt and nut assembly. Apply the same torque to each bolt. If a manufacturer recommends the use of a torque wrench, the specified torque will be listed in the manufacturer’s technical manual.

Another method for pulling down the nuts evenly is to stretch each bolt an equal amount and measure the distance from end to end of the bolt before and after tightening. Figure 3-31 shows the type of gauge used,

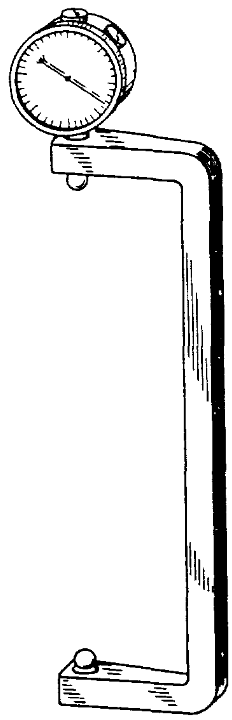


Figure 3-31.—Gauge used for measuring bolt elongation.

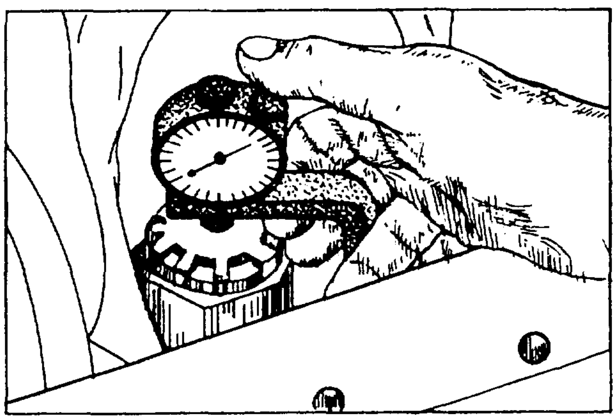


Figure 3-32.—Measuring bolt elongation.

and figure 3-32 illustrates the gauge in use. The proper elongation is listed in the engine manufacturer's technical manual.

After you reassemble a bearing, always bar or jack over the engine by hand through several revolutions. Check to see that all reciprocating and rotating parts function freely and that the main and connecting rod bearings do not bind on the crankshaft. Turn larger diesel engines over first by the manual jacking gear provided and then by the engine starting system.

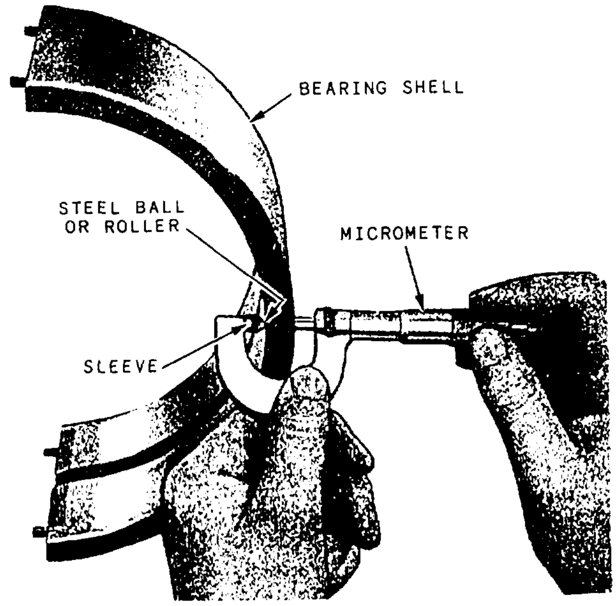


Figure 3-33.—Measuring bearing shell thickness.

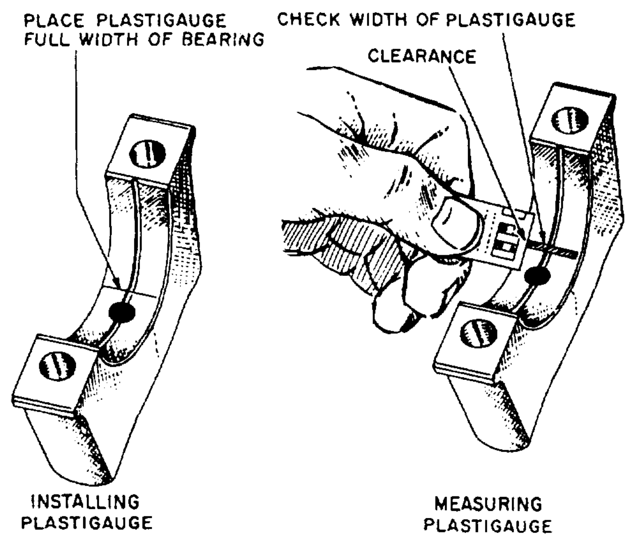


Figure 3-34.—Checking bearing clearance with a Plastlgage.

MEASURING BEARING CLEARANCES

Do not use leads, shim stock, or other such items to determine clearance of precision bearings. These items may seriously damage the soft bearing material. Instead, use a micrometer fitted with a spherical seat to measure the thickness of bearing shells. Place the spherical tip against the inside of the bearing shell to obtain an accurate reading and to prevent injury to the bearing material. Figure 3-33 shows a micrometer caliper fitted with a steel ball for measuring bearing thickness.

An alternate method for determining clearance is with a Plastigage (fig. 3-34). The Plastigage will not

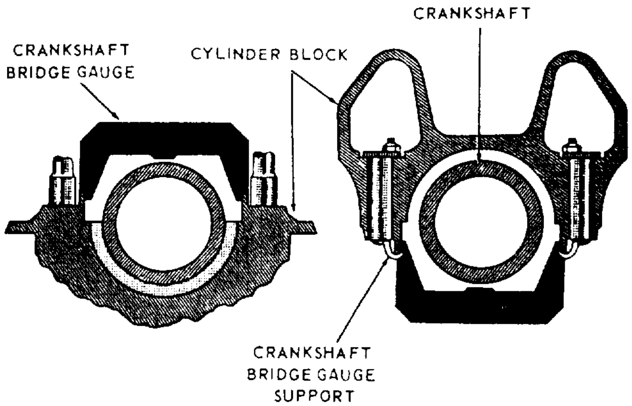


Figure 3-35.—Crankshaft bridge gauge.

leave an impression in the soft bearing metal because the gauge material is softer than the bearing. To use this method, place a length of the Plastigage of proper gauge across the bearing. Then, assemble the bearing cap and tighten it in place. DO NOT TURN the crankshaft, as that will destroy the Plastigage. After you install and properly fasten the bearing cap, remove it. Compare the width of the crushed Plastigage with the Plastigage chart to determine the exact clearance.

You must take measurements at specified intervals, usually at every overhaul, to establish the amount of bearing wear. Also take a sufficient number of crankshaft journal diameter measurements at suitable points to determine possible out-of-roundness.

With some types of engines, a crankshaft bridge gauge (fig. 3-35) is used to check the wear of the main bearing shells. To use the gauge, place it on the crankshaft and measure the clearance between the bridge gauge and the shaft with a feeler gauge. Any variation between the measured clearance and the correct clearance (usually stamped on the housing of each bearing) indicates that main bearing wear has occurred. The maximum limits of wear are listed in the manufacturer's technical manual. Some engine manufacturers recommend that bridge gauge readings be taken at every overhaul in conjunction with crank web deflection measurements.

The important point to remember is that if you cannot overhaul an engine due to lack of space, manpower, or expertise, you may request outside help by using an OPNAV Form 4790/2K. This form, when used as a work request, will be sent to a ship intermediate maintenance activity (SIMA). The SIMA will then accept or reject the work request. If the work request is accepted, the SIMA will order all repair parts, overhaul the engine, and perform an operational test according to the manufacturers' technical manuals and the NSTM, chapter 233.

As stated earlier in this section, maintenance cards, manufacturers' maintenance manuals, and various other instructions discuss repair procedures in detail. Therefore, this chapter will be limited to general information on some of the troubles encountered during overhaul, the causes of such troubles, and the methods of repair.

TROUBLESHOOTING INTERNAL-COMBUSTION ENGINES

The procedures for troubleshooting internal-combustion engines are somewhat similar for both diesel and gasoline engines. In many instances, the information that follows will apply to both types of engine. However, it also discusses principal differences. Since most of the internal-combustion engines used by the Navy are diesel, the following sections deal primarily with this type of engine.

This chapter is concerned with troubles that occur both when an engine is starting and running. The troubles are chiefly the kind that can be identified by erratic engine operation, warnings by instruments, or inspection of the engine parts and systems and that can be corrected without major repair or overhaul. There is also a section devoted to the systems of the gasoline engine that are basically different from those of the diesel engine.

Keep in mind that the troubles listed here are general and may or may not apply to a particular diesel engine. When you work with a specific engine, check the manufacturer's technical manual and any instructions issued by the Naval Sea Systems Command.

An engine may continue to operate even when a serious casualty is imminent. However, symptoms are usually present. Your success as a troubleshooter depends partially upon your ability to recognize these symptoms when they occur. You will use most of your senses to detect trouble symptoms. You may see, hear, smell, or feel the warning of trouble to come. Of course, common sense is also a requisite. Another factor in your success as a troubleshooter is your ability to locate the trouble once you decide something is wrong with the equipment. Then, you must be able to determine as rapidly as possible what corrective action to take. In learning to recognize and locate engine troubles, experience is the best teacher.

Instruments play an important part in detecting engine troubles. You should read the instruments and record their indications regularly. If the recorded indications vary radically from those specified by engine operating instructions, the engine is not operating properly and some type of corrective action must be taken. You must be familiar with the specifications in the engine operating instructions, especially those pertaining to temperatures, pressures, and speeds. You should know the probable effect on the engine when instrument indications vary considerably from the specified values. When variations occur in instrument indications, before taking any corrective action be sure the instruments are not at fault before you try corrective actions on the engine. Check the instruments immediately if you suspect them of being inaccurate.

Periodic inspections are also important in detecting engine troubles. Such inspections will reveal the failure of visible parts, presence of smoke, or leakage of oil, fuel, or water. Cleanliness is probably one of the greatest aids in detecting leakage.

When you secure an engine because of trouble, your procedure for repairing the casualty should follow an established pattern, if you have diagnosed the trouble. If you do not know the location of the trouble, find it. To inspect every part of an engine whenever trouble occurs would be an almost endless task. You can find the cause of the trouble much more quickly by following a systematic and logical method of inspection, Genernlly speaking, a well-trained troubleshooter can isolate the trouble by identifying it with one of the engine systems. Once you have associated the trouble with a particular system, the next step is to trace out the system until you find the cause of the trouble. Troubles generally originate in only one system, but remember that troubles in one system may cause damage to another system or to basic engine parts. When a casualty involves more than one system of the engine, trace each system separately and make corrections as necessary. It is obvious that you must know the construction, function, and operation of the various systems as well as the parts of each system for a specific engine before you can satisfactorily locate and remedy troubles.

Even though there are many troubles that may affect the operation of a diesel engine, satisfactory performance depends primarily on sufficiently high compression pressure and injection of the right amount of fuel at the proper time. Proper compression depends basically on the pistons, piston rings, and valve gear, while the right amount of fuel obviously depends on the fuel injectors and their actuating mechanism. Such troubles as lack of engine power, unusual or erratic operation, and excessive vibration may be caused by either insufficient compression or faulty injector action.

You can avoid many troubles by following the prescribed instructions for starting and operating the engine, The troubles discussed in the following sections do not comprise a complete list, nor do they all necessarily apply to all diesel engines because of differences in design. Specific information on troubleshooting for all the diesel engines used by the Navy would require more space than is available here.

Even though a successful troubleshooter generally associates certain troubles with a particular system or assembly, the following sections discuss troubles according to when they might be encountered, either before or after the engine starts.

ENGINE FAILS TO START

In general, the troubles that prevent an engine from starting are (1) the engine can neither be cranked nor barred over, (2) the engine cannot be cranked, but it can be barred over, and (3) the engine can be cranked, but it still fails to start. Figure 3-36 illustrates various conditions that commonly cause difficulties in cranking, jacking over, or starting the engine.

Engine Cannot Be Cranked nor Barred Over

Most prestarting instructions for large engines require you to turn the crankshaft one or more revolutions before applying starting power. If you cannot turn the crankshaft over, check the turning gear to be sure it is properly engaged. If the turning gear is properly engaged and the crankshaft still fails to turn over, check to see whether the cylinder test valves or indicator valves are closed and are holding water or oil in the cylinder. When the turning gear operates properly and the cylinder test valves are open but the engine still cannot be cranked or barred over, check for a serious problem. A piston or other part may be seized or a bearing may be fitting too tightly. Sometimes you may need to remove a part of an assembly to remedy the difficulty.

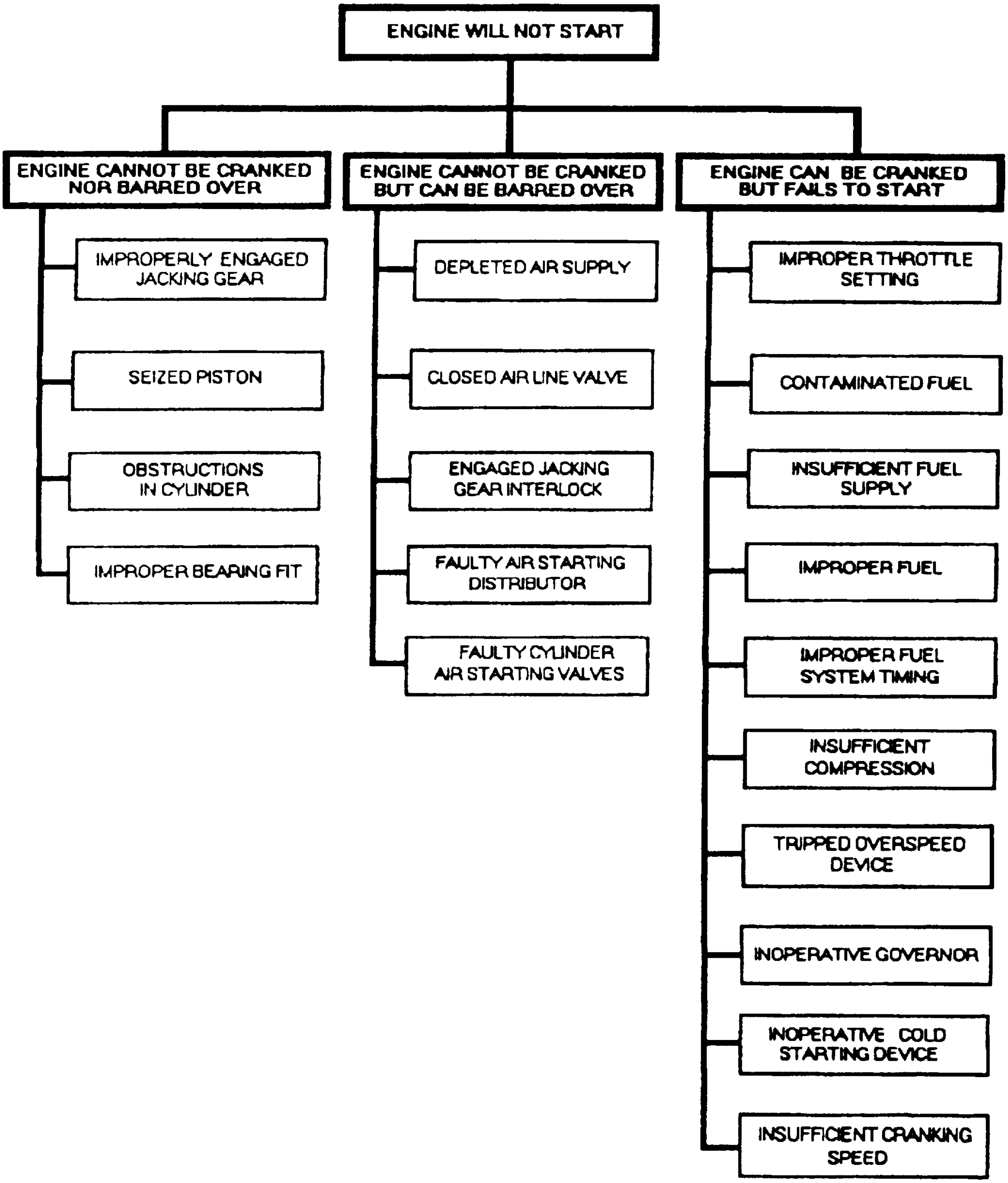


Figure 3-36.—Troubles that may prevent a diesel engine from starting.

Some engines have ports through which pistons can be inspected. If inspection reveals that the piston is defective, remove the piston assembly. Figure 3-37 illustrates testing for stuck piston rings through the scavenging-air port.

If the condition of an engine without cylinder ports indicates that a piston inspection is required, you must take the whole piston assembly out of the cylinder.

Engine bearings must be carefully fitted or installed according to the manufacturer's instructions. When an engine cannot be jacked over because of an improperly fitted bearing, someone probably failed to follow instructions when the unit was being reassembled.

Engine Cannot Be Cranked but Can Be Barred Over

You can trace most of the troubles that prevent an engine from cranking, but not serious enough to prevent barring over, to the starting system. Although other factors may prevent an engine from cranking, only troubles related to starting systems are identified in this chapter.

If an engine fails to crank when you apply starting power, first check the turning or jacking gear to be sure it is disengaged. If this gear is not the source of the trouble, the trouble is probably with the starting system.

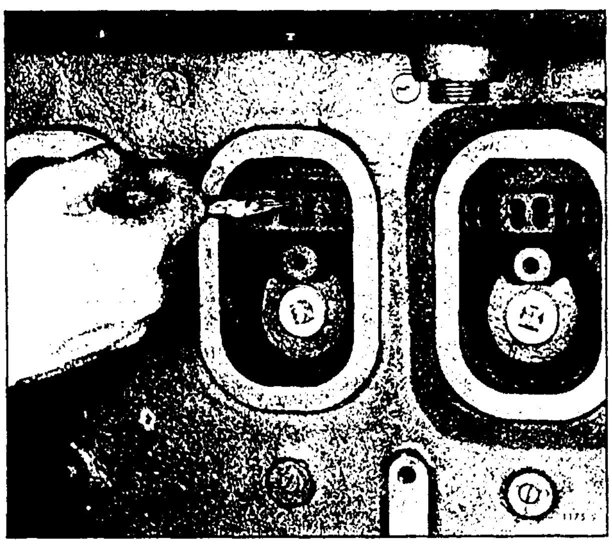


Figure 3-37.—Checking the condition of the piston rings.

Engine Can Be Cranked, but Fails to Start

Although the design of air starting systems may vary, the function remains the same. In general, such systems must have a source of air, such as the compressor or the ship's air system; a storage tank; air flask(s); an air timing mechanism; and a valve in the engine cylinder to admit the air during starting and to seal the cylinder while the engine is running.

All air starting systems have a unit that admits starting air to the proper cylinder at the proper time. The type of unit as well as its name-timer, distributor, air starting pilot valve, air starting distributor, or air distributor-may vary from one system to another. The types of air timing mechanisms are the direct mechanical lift, the rotary distributor, and the plunger-type distributor valve. The timing mechanism of an air starting system is relatively trouble-free except as noted in the following situations.

DIRECT MECHANICAL LIFT.—The direct mechanical lift air timing mechanism includes cams, pushrods, and rocker arms. These parts are subject to the same failures as engine cams, pushrods, and rocker arms. Therefore, you can find the causes of trouble in the actuating gear and the necessary maintenance procedures under information covering similar engine parts.

Most troubles are a result of improper adjustment. Generally, this involves the lift of the starting air cam or the timing of the air starting valve. The starting air cam must lift the air starting valve enough to give a proper clearance between the cam and the cam valve follower when the engine is running. If there is not enough clearance between these two parts, hot gases will flow between the valve and the valve seat, overheating them. Since the starting air cam regulates the opening of the air starting valve, check those with adjustable cam lobes frequently to ensure that the adjusting screws are tight.

Obtain the proper values for lift, tappet clearance, and time of valve opening for a direct mechanical lift timing mechanism from the manufacturer's technical manual for the particular engine. Make adjustments only as specified.

ROTARY DISTRIBUTOR.—The rotary distributor timing mechanism requires a minimum of maintenance, but there may be times when the unit becomes inoperative and you will need to disassemble and inspect it. Generally, the difficulty is caused by a scored rotor, a broken spring, or improper timing.

Foreign particles in the air can score the rotor, resulting in excessive air leakage. You must, therefore, keep the air supply as clean as possible. Lack of lubrication also causes scoring. If the rotor in a hand-oiled system becomes scored because of insufficient lubrication, the equipment could be at fault, or the lubrication instructions may not have been followed. To prevent problems in either a hand-oiled or pressure-lubricated system, check the piping and the passages to see that they are open. When scoring is not too serious, lap the rotor and body together. Use a thin coat of prussian blue to determine whether the rotor contacts the distributor body.

A broken spring may be the cause of an inoperative timing mechanism if a coil spring is used to maintain the rotor seal. If the spring is broken, replace it to ensure an effective seal.

An improperly timed rotary distributor will prevent an engine from cranking. Use the information given in the instructions for the specific engine to check the timing.

PLUNGER-TYPE DISTRIBUTOR VALVE.—In a plunger-type distributor valve timing mechanism, the valve requires little attention. However, it may stick occasionally and prevent the air starting system from functioning properly. On some engine installations, the pilot air valve of the distributor may not open, while on other installations this valve may not close. The trouble may be caused by dirt and gum deposits, broken return springs, or lack of lubrication. Deposits and lack of lubrication will cause the unit valve plungers to bind and stick in the guides, while a broken valve return spring will keep the plunger from following the cam profile. Disassemble and thoroughly clean a distributor valve that sticks; replace any broken springs.

Faulty Air Starting Valves

Air starting valves admit starting air into the engine cylinder and then seal the cylinder while the engine is running. These valves may be the pressure-actuated or mechanical-lift type.

PRESSURE-ACTUATED VALVES.—In a pressure-actuated valve, the most frequent trouble is sticking. The valve may stick open for a number of reasons. A gummy or resinous deposit may cause the upper and lower pistons to stick to the cylinders. (This deposit is formed by the oil and condensate that may be carried into the actuating cylinders and lower cylinders. Oil is necessary in the cylinders to provide lubrication and to act as a seal; however, moisture should be eliminated.) You can prevent this resinous deposit from forming by draining the system storage tanks and water traps as specified in the operating instruction. The deposit on the lower piston may be greater than that in the actuating cylinder because of the heat and combustion gases that add to the formation if the valve remains open. When the upper piston is the source of trouble, you can usually relieve the sticking, without removing the valve, by using light oil or diesel fuel and working the valve up and down. When you use this method, be sure that the valve surfaces are not burned or deformed. If this method does not relieve the sticking condition, you will need to remove, disassemble, and clean the valve.

Pressure-actuated starting valves sometimes fall to operate because of broken or weak valve return springs. Replacement is generally the only solution to this condition; however, some valves are constructed with a means of adjusting spring tension. In such valves, increasing the spring tension may eliminate the trouble.

Occasionally the actuating pressure of a valve will not release, and the valve will stick open or be sluggish in closing. The cause is usually clogged or restricted air passages. Combustion gases will enter the air passageways, burning the valve surfaces. These burned surfaces usually must be reconditioned before they will maintain a tight seal. Keeping the air passages open will eliminate extra maintenance work on the valve surfaces.

MECHANICAL LIFT VALVES.—The mechanical lift-type air starting valve is subject to leakage which, in general, is caused when the valve sticks open. Any air starting valve that sticks or leaks creates a condition that makes an engine hard to start. If the leakage in the air starting valve is excessive, the loss in pressure may prevent the engine from starting.

Leakage in this type of valve can be caused by an overtightened packing nut. The packing nut is sometimes overtightened to stop minor leaks around the valve stem when starting pressure is applied, but overtightening may prevent the air valve from seating. As in the pressure-actuated valve, there may not be enough return spring tension to return the valve to the valve seat after admitting the air charge.

Obstructions such as particles of carbon between the valve and valve seat will hold the valve open, permitting combustion gases to pass. A valve stem bent by careless handling during installation may also prevent a valve from closing properly.

If a valve hangs open for any of these reasons, hot combustion gases will leak past the valve and valve seat.

The gases burn the valve and seat and may cause a leak between these two surfaces even though the original causes of the sticking are eliminated.

Completely disassemble and inspect a leaking valve. It is subject to a resinous deposit similar to that found in a pressure-actuated air valve. Use a specified cleaning compound to remove the deposit. Be sure the valve stem is not bent. Check the valve and valve seat surfaces carefully. Eliminate scoring or discoloration by lapping with a fine lapping compound. You may use jewelers' rouge or talcum powder with fuel oil for lapping.

From the preceding discussion, you have learned that the air starting system may be the source of many troubles that will prevent an engine from cranking even though it can be barred over. You will avoid a few of these troubles by following prestarting and starting instructions. One such instruction, sometimes overlooked, is that of opening the valve in the air line. Obviously, with this valve closed the engine will not crank. Recheck the instructions for such oversights as a closed valve, an empty air storage receiver, or an engaged jacking gear before starting any disassembly.

ELECTRIC START MALFUNCTION

Electric starting system malfunctions fall into the following categories:

1. Nothing happens when the starter switch is closed.

2. The starter motor runs, but it does not engage the engine.

3. The starter motor engages, but it cannot turn the engine.

If nothing happens when you close the starter switch, there is a failure in the electrical system. The failure could be an open circuit caused by broken connections or burned out components. Test the circuit continuity to make sure the relay closes and the battery provides sufficient voltage and current to the starter circuit. If the circuit is complete, there may be resistance through faulty battery connections. Considerable current is needed to operate the solenoid and starter motor.

If the starter runs without engaging, it will produce a distinctive hum or whine. The lack of engagement is usually caused by dirt or corrosion, which keeps the solenoid or Bendix gears from operating properly.

If the starter motor engages the flywheel ring gear but is not able to turn the engine or cannot turn it quickly enough to obtain starting speed, the cause may be lack of battery power or, more likely, a mechanical problem. If the engine can be barred over, there is excessive friction in the meshing of the starter pinion and the ring gear. Either the teeth are burred, or the starter pinion is out of alignment. Either case would have been preceded by noise the last time the starter was used. A major repair may be necessary.

Other problems and malfunctions of electric starting systems are discussed in association with gasoline engines at the end of this chapter.

ENGINE CRANKS BUT FAILS TO START

Even when the starting equipment is in an operating condition, an engine may fail to start. Most troubles that prevent an engine from starting are associated with fuel and the fuel system. However, defective or inoperative parts or assemblies may be the source of some trouble. Failure to follow instructions may be the cause of an engine failing to start. The corrective action is obvious for such items as leaving the fuel throttle in the OFF position and leaving the cylinder indicator valves open. If an engine fails to start, follow the prescribed starting instructions and recheck the procedure.

Foreign Matter in the Fuel Oil System

In the operation of an internal-combustion engine, cleanliness is of paramount importance. This is especially true in the handling and care of diesel fuel oil. Impurities are the prime source of fuel pump and injection system troubles. Sediment and water cause wear, gumming, corrosion, and rust in a fuel system. Even though fuel oil is generally delivered clean from the refinery, handling and transferring increase the chances that fuel oil will become contaminated.

Corrosion often leads to replacement or at least to repair of the part. You must continually take steps to prevent water from accumulating in a fuel system, not only to eliminate the cause of corrosion but **also** to ensure proper combustion in the cylinders. Centrifuge all fuel, and drain the fuel filter cases periodically to prevent excessive collection of water.

Water in fuel will cause irreparable damage to the entire fuel system in a short time. It corrodes the fuel injection pump, where close clearances must be maintained, and also corrodes and erodes the injection nozzles. The slightest corrosion can cause a fuel injection pump to bind and seize which, if not corrected, will lead to excessive leakage. Water will erode the orifices of injection nozzles until they will not spray the fuel properly, thus preventing proper atomization. When this occurs, incomplete combustion and engine knocks result.

Air in the fuel system is another possible trouble that may prevent an engine from starting. Even if the engine will start, air in the fuel system will cause the engine to miss and knock, and perhaps to stall.

When an engine fails to operate, stalls, misfires, or knocks, there may be air in the high-pressure pumps and lines. In many systems, the expansion and compression of such air may take place even if the injection valves do not open. If this occurs, the pump is AIRBOUND. To determine if there is air in a fuel system, bleed a small amount of fuel from the top of the fuel filter; if the fuel appears quite cloudy, there are probably small bubbles of air in the fuel.

Insufficient Fuel Supply

An insufficient fuel supply may result from a defective or inoperative part in the system. Such items as a closed inlet valve in the fuel piping or an empty supply tank are more likely to be the fault of the operator than of the equipment. But an empty tank may be caused by leakage, either in the lines or in the tank

LEAKAGE.-You can usually trace leakage in the low-pressure lines of a fuel system to cracks in the piping. Usually these cracks occur on threaded pipe joints at the root of the threads. Such breakage is caused by the inability of the nipples and pipe joints to withstand shock, vibration, and strains resulting from the relative motion between smaller pipes and the equipment to which they are attached.

Metal fatigue can also cause breakage. Each system should have a systematic inspection of its fittings and piping to determine if all the parts are satisfactorily supported and sufficiently strong. In some instances, nipples may be connected to relatively heavy parts, such as valves and strainers, which are free to vibrate. Since vibration contributes materially to the fatigue of nipples, rigid bracing should be installed. When practicable, bracing should be secured to the unit itself, instead of to the hull or other equipment.

Breakage can also cause leakage in the high-pressure lines of a fuel system. The breakage usually occurs on either of the two end fittings of a line and is caused by lack of proper supports or by excessive nozzle opening pressure. Supports are usually supplied with an engine and should not be discarded. Excessive opening pressure of a nozzle-generally due to improper spring adjustment or to clogged nozzle orifices-may rupture the high-pressure fuel lines. A faulty nozzle usually requires removal, inspection, and repair plus the use of a nozzle tester.

Leakage from fuel lines may also be caused by improper replacement or repairs. When a replacement is necessary, always use a line of the same length and diameter as the one you remove. Varying the length and diameter of a high-pressure fuel line will change the injection characteristics of the injection nozzle.

In an emergency, you can usually repair a high-pressure fuel line by silver soldering a new fitting to the line. After making the silver solder repair, test the line for leaks and be certain no restrictions exist.

Most leakage trouble occurs in the fuel lines, but leaks may occasionally develop in the fuel tank. These leaks must be eliminated immediately because of potential fire hazard.

The principal causes of fuel tank leakage are improper welds and metal fatigue. Metal fatigue is usually the result of inadequate support; excessive stresses develop in the tank and cause cracks.

CLOGGED FUEL FILTERS-Another problem that can limit the fuel supply to such an extent that an engine will not start is clogged fuel filters. Definite rules for filter replacement cannot be established for all engines. But instructions generally state that elements will not be used longer than a specified time. Since there are reasons that an element may not always function properly for its expected service life, it should be replaced whenever it is suspected of being clogged.

Filter elements may become clogged because of dirty fuel, too small filter capacity, failure to drain the filter sump, and failure to use the primary strainer. Usually, clogging is indicated by such symptoms as stoppage of fuel flow, increase in pressure drop across the filter, increase in pressure upstream of the filter, or excessive accumulation of dirt on the element (observed when the filter is removed for inspection). Symptoms of clogged filters vary in different installations, and each installation should be studied for external symptoms, such as abnormal instrument indications and engine operation. If external indications are not apparent, visual inspection of the element will be necessary, especially if it is known or suspected that dirty fuel is being used.

Fuel filter capacity should at least equal fuel supply pump capacity. A filter with a small capacity clogs more rapidly than a larger one, because the space available for dirt accumulation is more limited. There are two standardized sizes of fuel filter elements-large and small. The small element is the same diameter as the large but is only one-half as long. This construction permits substitution of two small elements for one large element.

You can increase the interval of time between element changes by using the drain cocks on a filter sump. Removal of dirt through the drain cock will make room for more dirt to collect.

If new filter elements are not available for replacement and the engine must be operated, you can wash some types of totally clogged elements and get limited additional service. This procedure is for emergencies only. An engine must never be operated unless all the fuel is filtered; therefore, a “washed filter” is better than none at all.

Fuel must never flow from the supply tanks to the nozzles without passing through all stages of filtration. Strainers, as the primary stage in the fuel filtration system, must be kept in good condition if sufficient fuel is to flow in the system. Most strainers have a blade mechanism that can be turned by hand. If you cannot readily turn the scraper by hand, disassemble and clean the strainer. This minor preventive maintenance will prevent the scraping mechanism from breaking.

TRANSFER PUMPS.—If the supply of fuel oil to the system is to be maintained in an even and uninterrupted flow, the fuel transfer pumps must function properly. These pumps may become inoperative or defective to the point that they fail to discharge sufficient fuel for engine starting. Generally, when a pump fails to operate, some parts have to be replaced or reconditioned. For some types of pump, it is customary to replace the entire unit. However, for worn packing or seals, satisfactory repairs may be made. If plunger-type pumps fail to operate because the valves have become dirty, submerge and clean the pump in a bath of diesel oil.

Repairs of fuel transfer pumps should be made according to maintenance manuals supplied by the individual pump manufacturers.

Malfunctioning of the Injection System

The fuel injection system is the most intricate of the systems in a diesel engine. Since the function of an injection system is to deliver fuel to the cylinder at a high pressure, at the proper time, in the proper quantity, and properly atomized, special care and precautions must be taken in making adjustments and repairs.

HIGH-PRESSURE PUMP.-If a high-pressure pump in a fuel injection system becomes inoperative, an engine may fail to start. Information on the causes and remedies for an inoperative pump can be found in the manufacturer’s technical manual. Any ship using fuel injection equipment should have available copies of the applicable manufacturer’s technical manual.

TIMING.-Regardless of the installation or the type of fuel injection system used, the timing of the injection system must be correct to obtain maximum energy from the fuel. Early or late injection timing may prevent an engine from starting. Operation will be uneven and vibration will be greater than usual.

If fuel enters a cylinder too early, detonation generally occurs, causing the gas pressure to rise too rapidly before the piston reaches top dead center. This in turn causes a loss of power and high combustion pressure. Low exhaust temperature may be an indication that fuel injection is too early.

If fuel is injected too late in the engine cycle, overheating, lowered firing pressure, smoky exhaust, high exhaust temperature, or loss of power may occur.

Follow the instructions in the manufacturer’s technical manual to correct an improperly timed injection system.

Insufficient Compression

Proper compression pressures are essential if a diesel engine is to operate satisfactorily. Insufficient compression may cause an engine to fail to start. If you suspect low pressure as the reason, check the compression with the appropriate instrument. If the test indicates pressures below standard, disassembly is required for complete inspection and correction.

Inoperative Engine Governor

There are many troubles that may cause a governor to become inoperative. The most frequent trouble associated with starting an engine is generally caused by bound control linkage or, if the governor is hydraulic, by low oil level. Whether the governor is mechanical or hydraulic, binding of linkage is generally due to distorted, misaligned, defective, or dirty parts. If you suspect binding, move the linkage and governor parts by hand and check their movement. Eliminate any undue stiffness or sluggishness in the movement of the linkage.

Low oil level in hydraulic governors may be caused by oil leaking from the governor or failure to maintain the proper oil level. Leakage of oil from a governor can generally be traced to a faulty oil seal on the drive shaft or power piston rod, or to a poor gasket seal between parts of the governor case.

Check the condition of the oil seals if oil must be added too frequently to governors with independent oil supplies. Oil seal leakage may or may not be visible on external surfaces. There will be no external sign if leakage occurs through the seal around the drive shaft, while leakage through the seal around the power piston will be visible.

Oil seals must be kept clean and pliable. Store them properly so they do not become dirty or dry and brittle. Leaky oil seals cannot be repaired. They must be replaced. You can prevent some leakage troubles simply by following proper installation and storage instructions for the seals.

Most manufacturer's technical manuals supply information on the governor. Special hydraulic governor maintenance manuals made available by the Naval Sea Systems Command are the Marquette Governor Manual, NAVSHIPS 341-5505 (0341-LP-550-5000), and the Woodward Governor Manual, NAVSHIPS 341-5017 (0341-LP-501-7000).

Inoperative Overspeed Safety Devices

Overspeed safety devices are designed to shut off fuel or air in case of excessive engine speed. These devices must be maintained in operable condition at all times. Inoperative overspeed devices may also cause an engine not to start. They may be inoperative because of improper adjustment, faulty linkage, or a broken spring, or the overspeed device may have been accidentally tripped during the attempt to start the engine.

If the overspeed device fails to operate when the engine overspeeds, the engine may be secured by manually cutting off the fuel oil or the air supply to the engine. Most engines have special devices or valves to cut off the air or fuel in an emergency.

Insufficient Cranking Speed

If the engine cranks slowly, the necessary compression temperature cannot be reached. Low starting air pressure may be the cause of such trouble.

Slow cranking speed may also be the result of an increase in the viscosity of the lubricating oil. This trouble occurs during periods when the air temperature is lower than usual. The oil specified for use during normal operation and temperature is not generally suitable for cold climate operation.

IRREGULAR ENGINE OPERATION

As the engine operator, you must constantly be alert to detect any symptoms that might indicate trouble. Such symptoms may be sudden or abnormal changes in the supply, temperature, or pressure of the lubricating oil or cooling water. Color and temperature of the exhaust may also indicate abnormal conditions. Check them frequently. Fuel, oil, and water leaks indicate possible troubles. Keep the engine clean to make such leaks easier to spot.

You will soon become accustomed to the normal sounds and vibrations of a properly operating engine. If you are alert, an abnormal or unexpected change in the pitch or tone of an engine's noise or a change in the magnitude or frequency of a vibration will warn you that all is not well. A new sound such as a knock a drop in the fuel injection pressure, or a misfiring cylinder are other trouble warnings for which you should be constantly alert during engine operation.

The following discussion on possible troubles, their causes, and the corrective action necessary is general rather than specific. The information is based on instructions for some of the engines used by the Navy and is typical of most. A few troubles listed may apply to only one model. For specific information on any particular engine, consult the manufacturer's technical manual.

ENGINE STALLS FREQUENTLY OR STOPS SUDDENLY

We discussed earlier several of the troubles that may cause an engine to stall or stop. Such troubles as air in the fuel system, clogged fuel filters, unsatisfactory operation of fuel injection equipment, and incorrect governor action not only cause starting failures or stalling but also cause other troubles as well. For example, clogged fuel oil filters and strainers may lead to a loss of power, to misfires or erratic firing, or to low fuel oil pressure. Unfortunately, a single engine trouble does not always manifest itself as a single difficulty but may be the cause of several major difficulties.

Factors that may cause an engine to stall include misfiring, low cooling water temperature, improper application of load, improper timing, obstruction in the combustion space or in the exhaust system, insufficient intake air, piston seizure, and defective auxiliary drive mechanisms.

Misfiring

When an engine misfires or fires erratically or when one cylinder misfires regularly, the possible troubles are usually associated with the fuel or fuel system, worn parts, or the air cleaner or silencer. In determining what causes a cylinder to misfire, you should follow prescribed procedures in the appropriate technical manual. Procedures will vary among engines because of differences in the design of parts and equipment.

Many of the troubles caused by fuel contamination require overhaul and repair. However, a cylinder may misfire regularly in some systems because of the fuel pump cutout mechanism. Some fuel pumps have this type of mechanism so the fuel supply can be cut off from a cylinder to measure compression pressures. When a cylinder is misfiring, check first for an engaged cutout mechanism (if installed), and disengage it during normal engine operation.

LOSS OF COMPRESSION.–A cylinder may misfire due to loss of compression, which may be caused by a leaking cylinder head gasket, leaking or sticking cylinder valves, worn pistons, liners or rings, or a cracked cylinder head or block If loss of compression pressure causes an engine to misfire, check the compression pressure of each cylinder. Some indicators measure compression as well as firing pressure while the engine is running at full speed. Others check only the compression pressures with the engine running at a relatively slow speed. Figure 3-38 illustrates the application of some different types of pressure indicators.

After you install an indicator, operate the engine at the specified rpm and record the cylinder compression pressure. Follow this procedure on each cylinder in turn. The pressure in any one cylinder should not be lower than the specified psi, nor should the pressure for any one cylinder be excessively lower than the pressures in the other cylinders. The maximum pressure variation permitted between cylinders is given on engine data sheets or in the manufacturer's technical manual. A compression leak is indicated when the pressure in one cylinder is considerably lower than that in the other cylinders.

If a test indicates a compression leak, you will have to do some disassembly, inspection, and repair. Check the valve seats and cylinder head gaskets for leaks, and inspect the valve stems for sticking. A cylinder head or block may be cracked. If these parts are not the source of trouble, compression is probably leaking past the piston because of insufficient sealing of the piston rings.

Improper Cooling Water Temperature

If an engine is to operate properly, the cooling water temperature must be maintained within specified temperature limits. When cooling water temperature drops lower than recommended for a diesel engine,

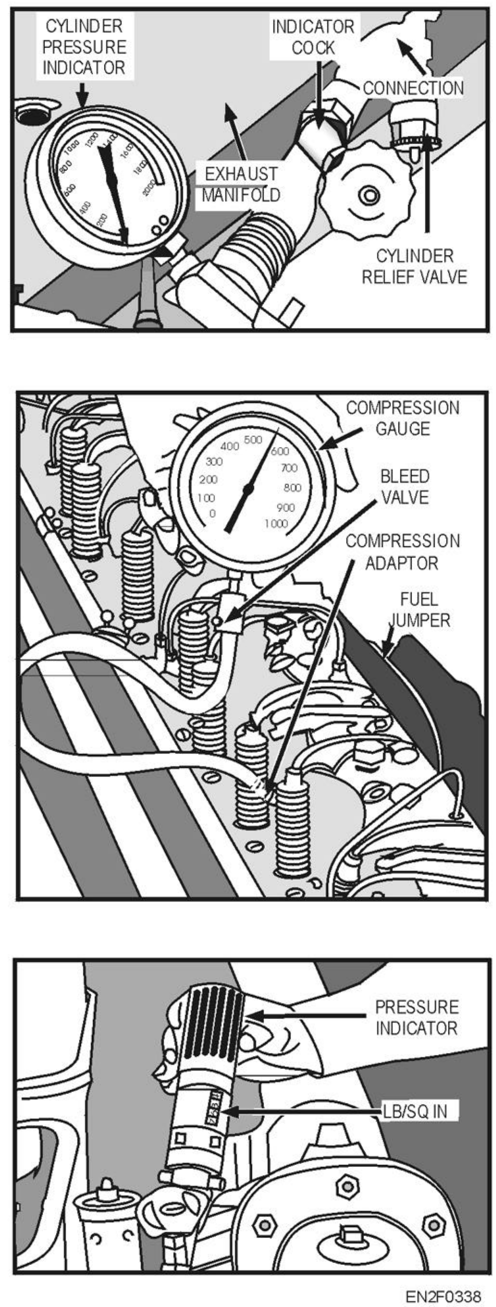


Figure 3-38.–Engine cylinder pressure indicator application.

ignition lag is increased, causing detonation, which results in rough operation. This may cause the engine to stall.

If the water temperature is higher than normal, the engine may not cool properly and may suffer heat damage. Water temperature is controlled primarily by a thermostatic valve (thermostat). The thermostat normally operates with a minimum of trouble. High or low cooling water temperature may indicate a malfunctioning thermostat. But before you remove the thermostat to check it, check to see whether the improper temperature may be caused by an insufficient engine load or an inaccurate temperature gauge.

When you suspect that the thermostat is not operating properly, remove it from the engine and test it. Use the following procedure to test the thermostat:

1. Obtain an open-topped container such as a bucket or a pot.

2. Heat the water to the temperature at which the thermostat is supposed to start opening. This temperature is usually specified in the appropriate technical manual. Use an accurate thermometer to check the water temperature. Use a hot plate or a burner as a source of heat. Stir the water frequently to ensure uniform distribution of the heat.

3. Suspend the thermostat by a string or a wire so that operation of the bellows will not be restricted.

4. Immerse the thermostat and observe its action. Check the thermometer readings carefully to see whether the thermostat begins to open at the recommended temperature. (The thermostat and thermometer must NOT touch the container.)

5. Increase the temperature of the water until the specified FULL OPEN temperature is reached. The immersed thermostat should be fully open at this temperature.

Replace the thermostat if it does not open when you test it, or if the temperatures at which the thermostat opens and closes vary more than allowed from the manufacturer's specifications.

The Fulton-Sylphon automatic temperature regulator is relatively trouble-free. The unit controls temperatures by a valve that bypasses some water around the cooler. This system provides a full flow of the water, although only a portion may be cooled. In other words, the full volume of cooling water is circulated at the proper velocity, which eliminates the possibility of steam pockets in the system.

Usually, if the automatic temperature regulator fails to maintain cooling water at the proper temperature, it simply needs to be readjusted. However, the element of the valve may be leaking or some part of the valve may be defective. Failure to follow the proper adjustment procedure is the only cause for improper adjustment of an automatic temperature regulator. Check and follow the proper procedure in the manufacturer's technical manual issued for the specific equipment.

Adjust the regulator by changing the tension of the spring (which opposes the action of the thermostatic bellows) with a special tool that turns the adjusting stem knob or wheel. Increasing the spring tension raises the temperature range of the regulator, and decreasing it lowers the temperature range.

When you place a new valve of this type into service, you must take a number of steps to ensure that the valve stem is the proper length and that all scale pointers make accurate indications. Make all adjustments according to the valve manufacturer's technical manual.

Obstruction in the Exhaust System

This type of trouble seldom occurs if proper installation and maintenance procedures are followed. When a part of an engine exhaust system is restricted, there will be an increase in the exhaust back pressure. This may cause high exhaust temperatures, loss of power, or even stalling. An obstruction that causes excessive back pressure in an exhaust system is generally associated with the silencer or muffler.

The manifolds of an exhaust system are relatively trouble-free if related equipment is designed and installed properly. Improper design or installation may cause water to back up into the exhaust manifold. In some installations, the design of the silencer may cause water to flow into the engine. The source of water that may enter an engine must be found and eliminated. This may require replacing some parts of the exhaust system with components of an improved design or may require relocating such items as the silencer and piping.

Inspect exhaust manifolds for water or symptoms of water. Accumulation of salt or scale in the manifold usually indicates that water has been entering from the silencer. Turbochargers on some engines have been known to seize because salt water entered the exhaust gas turhine from the silencer. Entry of water into an engine may also be detected by the presence of corrosion or of salt deposits on the engine exhaust valves.

If inspection reveals signs of water in an engine or in the exhaust manifold, take steps immediately to correct the trouble. Check the unit for proper installation. Wet-type silencers must be installed with the proper sizes of piping. If the inlet water piping is too large, too much water may be injected into the silencer. There must be continuous-type water drains on the silencer. If a silencer has no continuous drain and if the engine is at a lower level than the exhaust outlet, water may back up into the engine.

Dry-type silencers may become clogged with an excessive accumulation of oil or soot. When this occurs, exhaust back pressure increases, causing troubles such as high exhaust temperature, loss of power, or possible stalling. A dry-type silencer clogged with oil or soot is also subject to fire. Clogging can usually be detected by fire, soot, or sparks coming from the exhaust stack An excessive accumulation of oil or soot in a dry-type silencer may be due to a number of factors, such as failure to drain the silencer, poor condition of the engine, or improper engine operating conditions.

Insufficient Intake Air

Insufficient intake air, which may cause an engine to stall or stop, may be due to blower failure or to a clogged air silencer or air filter. Even though all other engine parts function perfectly, efficient engine operation is impossible if the air intake system fails to supply a sufficient quantity of air for complete combustion of the fuel.

CLOGGED AIR CLEANERS AND SILENCERS.—Sometimes an engine will fire erratically or misfire because of a clogged air cleaner or silencer. Air cleaners must be cleaned at specified intervals, as recommended in the engine manufacturer's technical manuals. A clogged cleaner reduces the intake air, thereby affecting the operation of the engine. Clogged air cleaners may cause not only misfiring or erratic firing but also such difficulties as hard starting, loss of power, engine smoke, and overheating.

When you clean an air cleaner element, if you use a volatile solvent, be SURE the element is dry before you reinstall it on the engine. Volatile solvents are excellent cleaning agents but, if permitted to remain in the filter, may cause engine overspeeding or a serious explosion.

Oil-bath type air cleaners and filters cause very little trouble if serviced properly. Cleaning directions are usually given on the cleaner housing. The frequency of cleaning is usually based on a specified number of operating hours, but more frequent cleaning may be necessary where unfavorable conditions exist.

When you fill an oil bath-type cleaner, follow the manufacturer's instructions. Most air cleaners of this type have a FULL mark on the oil reservoir. Filling beyond this mark does not increase the efficiency of the unit and may lead to serious trouble. When the oil bath is too full, the intake air may draw oil into the cylinders. This excess oil-air mixture, over which there is no control, may cause an engine to "run away," resulting in serious damage.

BLOWER FAILURE.—Troubles that may prevent a centrifugal blower from performing its function usually involve damage to the rotor shaft, thrust bearings, turbine blading, nozzle ring, or blower impeller. Damage to the rotor shaft and thrust bearings usually results from insufficient lubrication, an unbalanced rotor, or operation with excessive exhaust temperature.

Centrifugal blower lubrication problems may be caused by failure of the oil pump to prime, low lube oil level, clogged oil passages or oil filter, or a defective relief valve, which is designed to maintain proper lube oil pressure.

If an unbalanced rotor is the cause of shaft or bearing trouble, there will be excessive vibration. Unbalance may be caused by a damaged turbine wheel blading or by a damaged blower impeller.

Operating a blower when the exhaust temperature is above the specified maximum safe temperature generally causes severe damage to turbocharger bearings and other parts. Make every effort to find and eliminate causes of excessive exhaust temperature before the turbocharger is damaged.

Turbine blading damage may be caused by operating with an excessive exhaust temperature, operating at excessive speeds, bearing failures, failure to drain the turbine casing, the entrance of foreign bodies, or by turbine blades that break loose.

Damage to an impeller may be caused by thrust or shaft bearing failure, entrance of foreign bodies, or loosening of the impeller on the shaft.

Since blowers are high-speed units and operate with a very small clearance between parts, minor damage to a part could cause extensive blower damage and failure.

Although there is considerable difference in operating principle and construction between the positive-displacement blower (Roots) and the axial-flow positive-displacement blower (Hamilton-Whitfield), the problems of operation and maintenance are similar.

Some of the troubles in a positive-displacement blower are similar to those already mentioned in our discussion of the centrifugal-type blowers. However, the source of some troubles may be different because of construction differences.

Positive-displacement blowers have a set of gears to drive and synchronize the rotation of the rotors. Many of these blowers are driven by a serrated shaft. Regardless of construction differences, the basic problem in both types of blowers is in maintaining the necessary small clearances. If these clearances are not maintained, the rotors and the case will be damaged and the blower will fail to perform its function.

Worn gears are one source of trouble in positive-displacement blowers. A certain amount of gear wear is expected, but damage caused by excessively worn gears indicates improper maintenance procedures. Whenever you inspect a positive-displacement blower, record the backlash values, according to PMS. You can use this record to establish the rate of increase in wear, to estimate the life of the gears, and to determine when it will be necessary to replace the gears.

Scored rotor lobes and casing may cause blower failure. Scoring of blower parts may be caused by worn gears, improper timing, bearing failure, improper end clearance, or by foreign matter. Any of these troubles may be serious enough to cause the rotors to contact and damage the blower extensively.

Timing of blower rotors involves both gear backlash and the clearances between the leading and trailing edges of the rotor lobes and between rotor lobes and the casing. You can measure the clearance between these parts with thickness gauges, as illustrated in figure 3-39. If the clearances are incorrect, check the backlash of the drive gear first. Then retime the rotors according to the method outlined in the manufacturer’s technical manual.

Failure of serrated blower shafts may be due to failure to inspect the parts or of improper replacement of parts. When you inspect serrated shafts, be sure that they fit snugly and that wear is not excessive. When

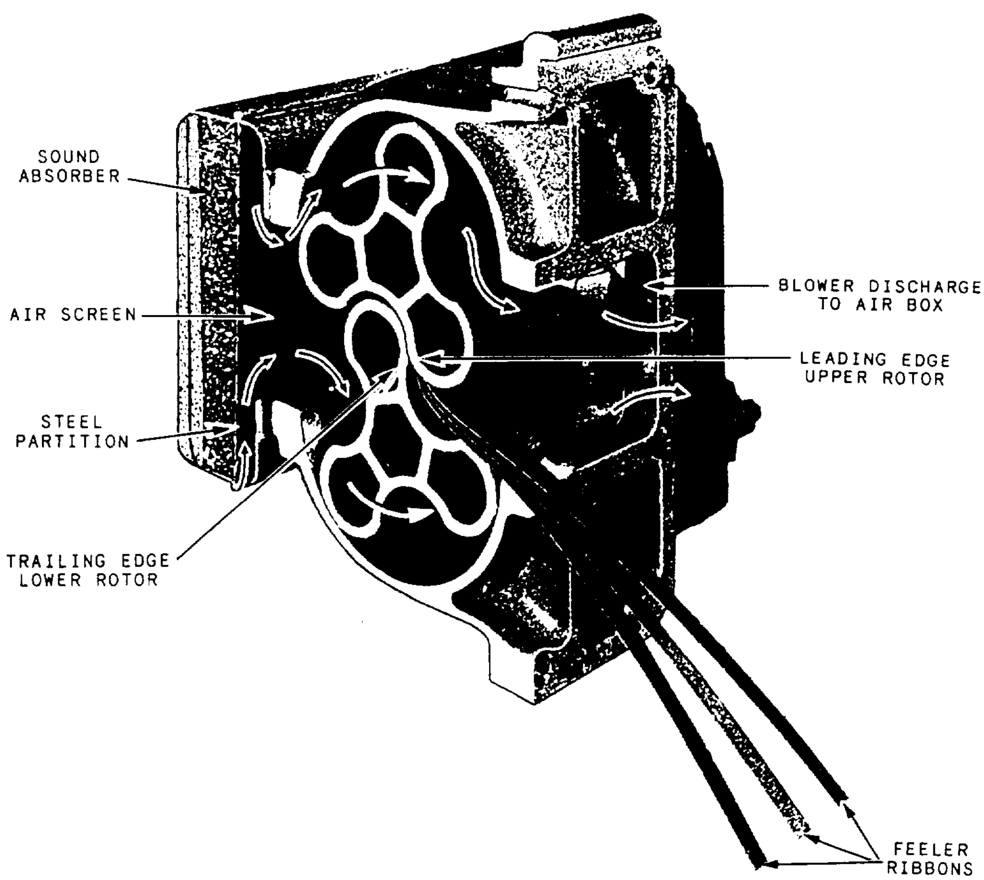


Figure 3-39.—Checking clearances of positive-displacement blower lobes.

serrations of either the shaft or the hub have failed for any reason, replace both parts.

Obstruction in the Combustion Space

Such items as broken valve heads and valve stem locks or keepers that come loose because of a broken valve spring may cause an engine to come to an abrupt stop. If an engine continues to run when such obstructions are in the combustion chamber, the piston, liner, head, and injection nozzle will be severely damaged.

Piston Seizure

Piston seizure may also cause an engine to stop suddenly. The piston becomes galled and scuffed. When this occurs, the piston may possibly break or extensive damage may be done to other major engine parts. The principal causes of piston seizure are insufficient clearance, excessive temperatures, or inadequate lubrication.

Defective Auxiliary Drive Mechanisms

Defects in auxiliary drive mechanisms may cause an engine to stop suddenly. Since most troubles in gear trains or chain drives require some disassembly, this discussion will be limited to the causes of such troubles.

Gear failure is the principal trouble in gear trains. Engine failure and extensive damage can occur because of a broken or chipped gear. If you hear a metallic clicking noise in the vicinity of a gear housing, it is almost a certain indication that a gear tooth has broken.

Gears are most likely to fail because of improper lubrication, corrosion, misalignment, torsional vibration, excessive backlash, wiped bearings and bushings, metal obstructions, or improper manufacturing procedures.

Gear shafts, bushings and bearings, and gear teeth must be checked during periodic inspections for scoring, wear, and pitting. All oil passages, jets, and sprays should be cleaned to ensure proper oil flow. All gear-locking devices must fit tightly to prevent longitudinal gear movement.

Chains are used in some engines for camshaft and auxiliary drives; in other engines, chains are used to drive *certain* auxiliary rotating parts. Troubles in chain drives are usually caused by wear or breakage. Troubles of this nature may be caused by improper chain tension, lack of lubrication, sheared cotter pins, or misalignment.

Figure 3-40 is a summary of the possible troubles that may cause an engine to stall frequently or stop suddenly. There may be some doubt as to the difference between stalling and stopping. In reality, there is none unless we associate certain troubles with each. In general, troubles that cause FREQUENT STALLING are those that can be eliminated with minor adjustments or maintenance. If such troubles are not eliminated, it is quite possible that the engine can be started, only to stall again. Failure to eliminate some of the troubles that cause frequent stalling may lead to troubles that cause SUDDEN STOPPING.

ENGINE WILL NOT CARRY A LOAD

Many of the troubles that can lead to loss of power in an engine may also cause the engine to stop and stall suddenly or may even prevent it from starting. Compare the list of some of the troubles that may cause a power loss (fig. 3-41) with those in figures 3-36 and 3-40. Such items as insufficient air, insufficient fuel, and faulty operation of the governor appear on all three charts. Many of the troubles listed are closely related, and the elimination of one may eliminate others.

The operator of an internal-combustion engine may be confronted with additional major difficulties, such as those indicated in figure 3-42. Here, again, you can see that many of these possible troubles are similar to those that have already been discussed in connection with starting failures and with engine stalling and stopping. The discussion that follows covers only those troubles not previously considered.

ENGINE OVERSPEEDS

When an engine overspeeds, the trouble is usually caused by either the governor mechanism or the fuel control linkage, as previously discussed When you need information on a specific fuel system or speed control system, check the manufacturer’s technical manual and the special technical manuals for the particular system. These special manuals are available for the most widely used models of hydraulic governors and overspeed trips, and they contain specific details on testing, adjusting, and repairing each controlling device.

ENGINE HUNTS OR WILL NOT STOP

Some troubles that may cause an engine to hunt, or vary its rpm at constant throttle setting, are similar to those that may cause an engine to resist stopping. Generally, these two forms of irregular engine operation

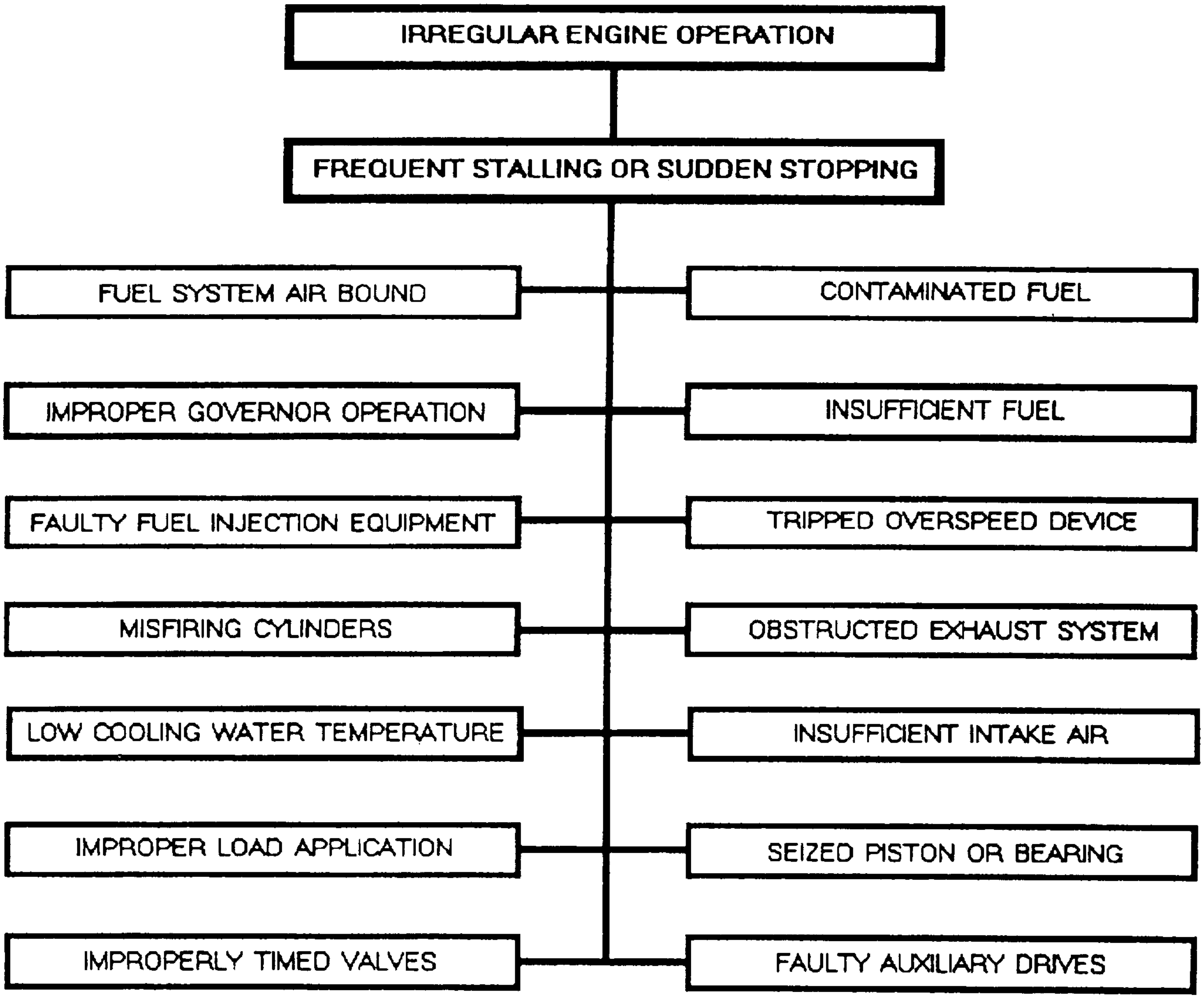


Figure 3-40.—Possible troubles that may cause an engine to stall frequently or to stop suddenly.

are caused by troubles originating in the speed control system and the fuel system.

Speed Control System

The speed control system of an internal-combustion engine includes those parts designed to maintain the engine speed at some exact value or between desired limits, regardless of changes in the load on the engine. Governors are provided to regulate fuel injection so the speed of the engine can be controlled as the load is applied. Governors also prevent overspeeding as may happen in rough seas when the load is suddenly reduced as the propellers leave the water.

Fuel Control Racks

Fuel control racks that have become sticky or jammed may cause governing difficulties. If the control rack of a fuel system is not functioning properly, the engine speed may increase as the load is removed, the engine may hunt continuously, or it may hunt only when the load is changed. A sticky or jammed control rack may prevent the engine from responding to changes in throttle setting and may even prevent it from stopping. Any such condition could be serious in an emergency situation. Your job is to make every effort possible to prevent such conditions from occurring.

You can check for a sticky rack by stopping the engine, disconnecting the linkage to the governor, and then attempting to move the rack by hand. There should

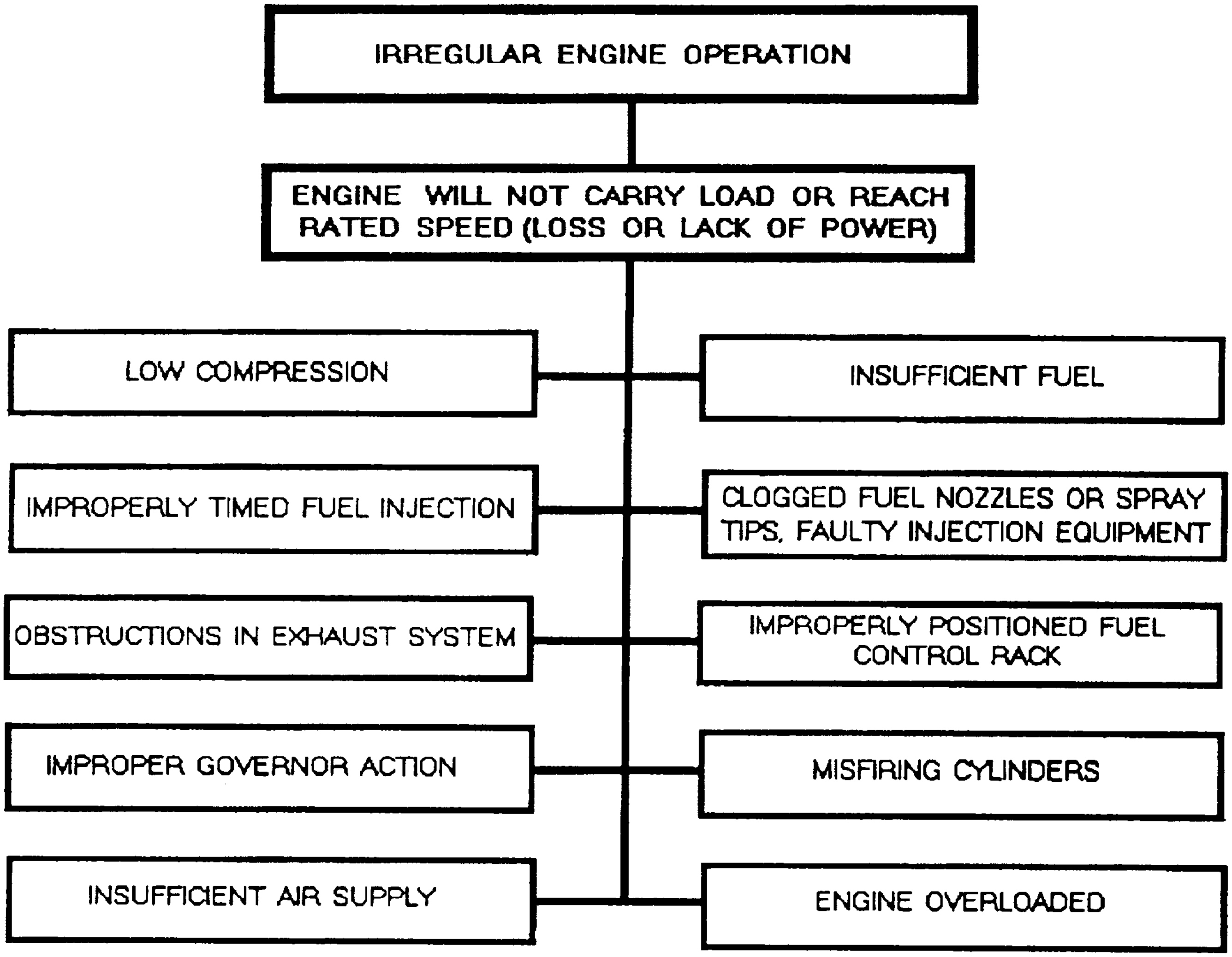


Figure 3-41.—Possible causes of insufficient power in an engine.

be no apparent resistance to the motion of the rack if the return springs and linkage are disconnected. A stuck control rack may be caused by the plunger's sticking in the pump barrel; dirt in the rack mechanism; damage to the rack, sleeve, or gear; or improper assembly of the injector pump.

If the rack sticks or jams, you must determine the cause and replace any damaged parts. If sticking is due to dirt, thoroughly clean all the parts to correct the trouble. You can avoid errors in assembly by carefully studying the assembly drawings and instructions.

Leakage of Fuel Oil

Leakage of fuel oil from the injectors may cause an engine to continue to operate when you attempt to shut it down. Regardless of the type of fuel system, the results of internal leakage from injection equipment are, in general, somewhat the same. Injector leakage will cause unsatisfactory engine operation **because** of the excessive amount of fuel entering the cylinder. Leakage may also cause detonation, crankcase dilution, smoky exhaust, loss of power, and excessive carbon formation on the spray tips of nozzles and other surfaces of the combustion chamber.

Accumulation of Lube Oil

Another trouble that may prevent you from stopping an engine is accumulation of lube oil in the intake air passages-manifold or air box. Such an accumulation creates an extremely dangerous condition. You can detect excess oil by removing the inspection plates on the covers and examining the air box and manifold. If you discover oil, remove it and perform the necessary

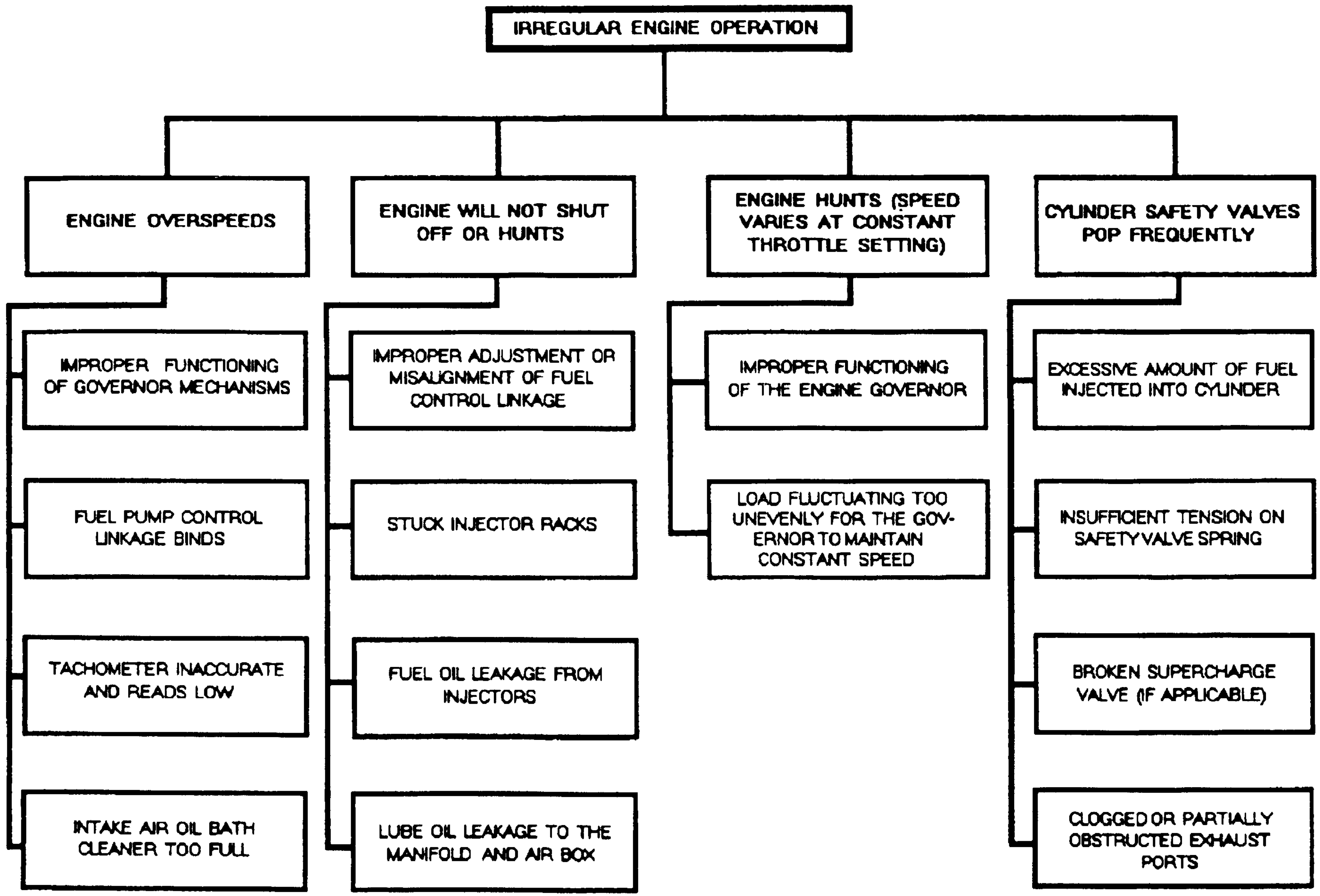


Figure 3-42.–Additional causes of irregular engine operation.

corrective maintenance. If oil is drawn suddenly in large quantities from the manifold or air box into the cylinder of the engine and burns, the engine may run away. The engine governor has no control over the sudden increase in speed.

An air box or air manifold explosion is also a possibility if excess oil is allowed to accumulate. Some engine manufacturers have provided safety devices to reduce the hazards of such explosions.

Excess oil in the air box or manifold of an engine also increases the tendency of carbon to form on liner ports, cylinder valves, and other parts of the combustion chamber.

The causes of excessive lube oil accumulation in the air box or manifold will vary depending on the specific engine. Generally, the accumulation is due to an obstruction in either the air box or separator drains.

In an effort to reduce the possibility of crankcase explosions and runaways, some engine manufacturers have designed a means to ventilate the crankcase. In some engines, a passage between the crankcase and the intake side of the blower provides ventilation. In other engines, an oil separator or air maze in the passage between the crankcase and blower intake provides ventilation.

In either type of installation, stopped up drains will cause an excessive accumulation of oil. Drain passages must be kept open by proper cleaning whenever necessary.

Oil may enter the air box or manifold from sources other than crankcase vapors. A defective blower oil seal, a carryover from an oil-type air cleaner, or defective oil piping may be the source of trouble.

Another possible source may be an excessively high oil level in the crankcase. Under this condition, an oil fog is created in some engines by the moving parts. An oil fog may also be caused by excessive clearance in the connecting rod and main journal bearings. In some types of crankcase ventilating systems, the oil fog will be drawn into the blower. When this occurs, an abnormal amount of oil may accumulate in the air box. Removal of the oil will not remove the trouble. The cause of the accumulation must be determined and the necessary repair made.

If a blower oil seal is defective, replacement is the only satisfactory method of correction. When you install new seals, be sure the shafts are not scored and the bearings are in satisfactory condition. Take special precautions during the installation to avoid damaging the oil seals. Damage to an oil seal during installation is usually not discovered until the blower has been reinstalled and the engine has been put into operation. Be sure an oil seal gets the necessary lubrication. The oil not only lubricates the seal, reducing friction, but also carries away any heat that is generated. For most purposes, soak new oil seals in clean, light lube oil before you install them.

CYLINDER SAFETY VALVES

On some engines, a cylinder relief (safety valve) is provided for each cylinder. The valve opens when the cylinder pressure exceeds a safe operating limit. The valve opens or closes a passage leading from the combustion chamber to the outside of the cylinder. The valve face is held against the valve seat by spring pressure. Tension on the spring is varied by an adjusting nut, which is locked when the desired setting is attained. The desired setting varies with the type of engine and may be found in the manufacturer’s technical manual.

Cylinder relief valves should be set at the specified lifting pressure. Continual lifting (popping) of the valves indicates excessive cylinder pressure or malfunction of the valves, either of which should be corrected immediately. Repeated lifting of a relief valve indicates that the engine is being overloaded, the load is being applied improperly, or the engine is too cold. Also, repeated lifting may indicate that the valve spring has become weakened, ignition or fuel injection is occurring too early, the injector is sticking and leaking, too much fuel is being supplied, or, in air injection engines, the spray valve air pressure is too high. When frequent popping occurs, stop the engine and determine and remedy the cause of the trouble. In an emergency, cut off the fuel supply in the affected cylinder. NEVER lock relief valves closed, except in an emergency. When you must take emergency measures, be sure to repair or replace the valves, as necessary, as soon as possible.

When excessive fuel is the cause of frequent safety valve lifting, the trouble may be due to the improper functioning of a high-pressure injection pump, a leaky nozzle or spray valve, or a loose fuel cam (if adjustable). In some systems, such as the common rail, the fuel pressure may be too high.

A safety valve that is not operating properly should be removed, disassembled, cleaned, and inspected. Check the valve and valve seat for pitting and excessive wear and the vale spring for possible defective conditions. When you remove a safety valve for any reason, you must reset the spring tension. This procedure varies to some extent, depending on the valve construction.

Except in emergencies, it is advisable to shut the engine down when troubles cause safety valve popping.

Clogged or partially obstructed exhaust ports may also cause the cylinder safety valve to lift. This condition will not occur often if proper planned maintenance procedures are followed. If it does occur, the resulting increase in cylinder pressure may be enough to cause safety valve popping. Clogged exhaust ports will also cause overheating of the engine, high exhaust temperatures, and sluggish engine operation.

You can prevent clogged cylinder ports by removing carbon deposits at prescribed intervals. Some engine manufacturers make special tools for port cleaning. Round wire brushes of the proper size are satisfactory for this work You must be careful in cleaning cylinder ports to prevent carbon from entering the cylinder-bar the engine to such a position that the piston blocks the port.

SYMPTOMS OF ENGINE TROUBLE

In learning to recognize the symptoms that may help locate the causes of engine trouble, you will find that experience is the best teacher. Even though written instructions are essential for efficient troubleshooting, the information usually given serves only as a guide. It is very difficult to describe the sensation that you should feel when checking the temperature of a bearing by hand; the specific color of exhaust smoke when pistons and rings are worn excessively; and, for some engines, the sound that you will hear if the crankshaft counterweights come loose. You must actually work with the equipment to associate a particular symptom with a particular trouble. Written information, however, can save you a great deal of time and eliminate much unnecessary work. Written instructions will make detection of troubles much easier in practical situations.

A symptom that indicates that trouble exists may be in the form of an unusual noise or instrument indication, smoke, or excessive consumption or contamination of the lube oil, fuel, or water. Figure 3-43 is a general listing of various trouble symptoms that you may encounter.

NOISES

The unusual noises that may indicate that trouble exists or is impending may be classified as pounding, knocking, clicking, and rattling. Each type of noise must be associated with certain engine parts or systems that might be the source of trouble.

Pounding or hammering is a mechanical knock (not to be confused with a fuel knock). It may be caused by a loose, excessively worn, or broken engine part. Generally, troubles of this nature will require major repairs.

Detonation (knocking) is caused by the presence of fuel or lubricating oil in the air charge of the cylinders during the compression stroke. Excessive pressures accompany detonation. If detonation is occurring in one or more cylinders, stop the engine immediately to prevent possible damage.

Clicking noises are generally associated with an improperly functioning valve mechanism or timing gear. If the cylinder or valve mechanism is the source of metallic clicking, the trouble may be due to a loose valve stem and guide, insufficient or excessive valve tappet clearances, a loose cam follower or guide, broken valve springs, or a valve that is stuck open. A clicking in the timing gear usually indicates that there are some damaged or broken gear teeth.

Rattling noises are generally due to vibration of loose engine parts. However, an improperly functioning vibration damper, a failed antifriction bearing, or a gear-type pump operating without prime are also possible sources of rattling noises.

When you hear a noise, first make sure it is a trouble symptom. Each diesel engine has a characteristic noise at any specific speed and load. The noise will change with a change in speed or load. As an operator, you must become familiar with the normal sounds of the engine. Investigate all abnormal sounds promptly. Knocks that indicate a trouble may be detected and located by special instruments or by the use of a “sounding bar,” such as a solid iron screwdriver or bar.

INSTRUMENT INDICATIONS

As an engine operator, you will probably rely more on the instruments to warn you of impending troubles than on all the other trouble symptoms combined. Regardless of the type of instrument being used, the indications are of no value if the instrument is inaccurate. Be sure an instrument is accurate and operating properly before you accept a low or high reading. Test all instruments at specified intervals or whenever you suspect them of being inaccurate.

SMOKE

Smoke can be quite useful as an aid in locating some types of trouble, especially if used in conjunction with other trouble symptoms.

The color of exhaust smoke, a good indication of engine performance, can also be used as a guide in troubleshooting. The exhaust of an efficiently operating engine has little or no color. A dark, smoky exhaust indicates incomplete combustion; the darker the color, the greater the amount of unburned fuel in the exhaust. Incomplete combustion may be due to a number of troubles. Some manufacturers associate a particular type of trouble with the color of the exhaust. The more serious troubles are generally identified with either black or bluish-white exhaust colors.

NOISES	INSTRUMENT INDICATIONS			SMOKE	CONTAMINATIOF OF LUBE OIL, FUEL, OR WATER
	PRESSURE	TEMPERATURE	SPEED		
Pounding (mechanical)	Low lube oil pressure	Low lube oil temperature	Idling speed not normal	Black exhaust smoke	Fuel oil in the lube oil
	High lube oil pressure	High lube oil temperature	Maximum speed not normal	Bluish-white exhaust smoke	Water in the lube oil
Knocking (detonation)	Low fuel oil pressure (in low-pressure fuel supply system)	Low cooling water temperature (fresh)		Smoke arising from crankcase	Oil or grease in the water Water in the fuel oil
Clicking (metallic)	Low cooling water pressure (fresh)	High cooling water temperature (fresh)		Smoke arising from cylinder head Smoke from engine auxiliary equipment (blowers, pumps, etc.)	Air or gas in the water Metal particles in lube oil
	Low cooling water pressure (salt)	Low cylinder exhaust temperature			
Rattling	High cooling water pressure (salt)	High exhaust temperature in one cylinder			
	Low compression pressure				
	Low firing pressure				
	High firing pressure				
	Low scavenging air receiver pressure (supercharge engine)				
	High exhaust back pressure				

Figure 3-43.—Symptoms of engine troubles.

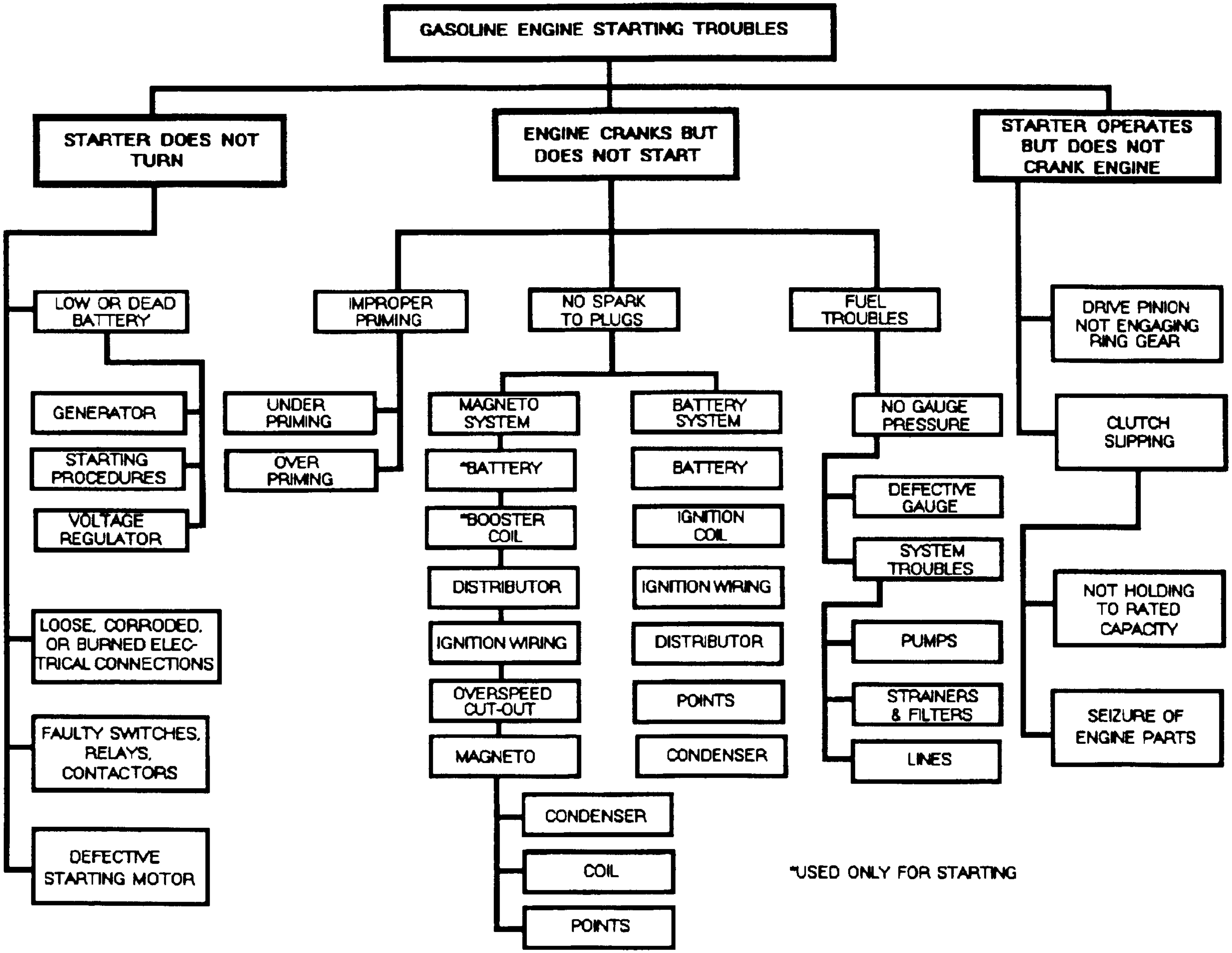


Figure 3-44.–Possible sources of trouble when a gasoline engine fails to start.

EXCESSIVE CONSUMPTION OF LUBE OIL, FUEL, OR WATER

You should suspect engine trouble whenever excessive consumption of any of the essential liquids occurs. The possible troubles indicated by excessive consumption will depend on the system in question. Leakage, however, is one trouble that may be common to all. Before you start any disassembly, check for leaks in the system in which excessive consumption occurs.

TROUBLESHOOTING GASOLINE ENGINES

The troubleshooting procedures used for a marine gasoline engine are, in many ways, similar to those for a diesel engine. The two types of engines are quite similar with two exceptions, the manner of getting fuel and air into the cylinders and the method of ignition.

This section deals primarily with the systems that differ in the gasoline and diesel engines. In addition, troubleshooting information is given on the electrical systems.

Even though most electrical maintenance and repair is the responsibility of an Electrician's Mate, you, as an Engineman, can reduce the amount of electrical troubles by following the correct operating procedures. Most electrical system troubles develop from improper use, care, or maintenance.

The following information will help you detect electrical troubles and take corrective action.

When a gasoline engine fails to start, one of three conditions exists. The engine is not free to turn, the starter does not crank the engine, or the engine cranks but does not start. Figure 3-44 lists many of the conditions and sources of such difficulties,

If the engine will not turn over, some part is probably seized In this case you should make a through inspection, which may necessarily include some disassembly.

STARTER DOES NOT RUN

If the starter fails to turn, the trouble can usually be traced to the battery, connections, switch, or starter motor.

Symptoms of battery trouble generally occur before the charge gets too low to perform the required work Battery failure is normally preceded by a gradual decline in the strength of the battery charge. A dead battery may be the result of insufficient charging, damaged plates, or improper starting technique.

The generator, used to maintain the charge of the starting battery, may become defective. The normal symptoms are a low battery charge when the engine is started and a zero or low ammeter reading when the engine is running.

The battery must be in good condition to ensure the proper operation of the ignition system. A starter draws a heavy current from the best of batteries. When the battery is weak, it will be unable to operate the ignition system satisfactorily for starting because the heavy starting current will drop the voltage to an extremely low value.

NOTE: Keep flames and sparks of all kinds away from the vicinity of storage batteries. A certain amount of hydrogen gas is given off from a battery at all times. In confined spaces this gas can form a dangerous explosive mixture.

When you use tools around a battery, be careful not to short circuit the battery terminals. Never use a tool or metal object to make a so-called test of a storage battery.

Keep batteries in exposed locations subject to low temperatures fully charged during cold weather. In extreme cold weather, remove storage batteries and place them in a warm compartment, if possible.

Electrical connections are another possible source of trouble if the starter does not turn. All connections must be tight and free from corrosion to provide maximum voltage and amperage from the battery. Battery terminals, since they are more vulnerable to corrosion, looseness, and burning, are the principal sources of trouble.

Burned battery terminals may be caused by a loose connection, a corroded terminal, or a short circuit. Burning of terminals usually occurs when an engine is being started Burning may be indicated by such things as smoke, a flash, or a spattering of molten metal in the vicinity of the battery. Usually, the starting motor will cease to turn after these symptoms appear.

Switches, electrical relays, or contactors that are defective or inoperative may be the reason a starter will not turn. Contactors, being subject to extremely high current, must be maintained in the best possible condition. Starting contactors are either manually or magnetically operated and are designed to be operated for only short periods of time.

Starter motor troubles can be traced for the most part to the commutator, brushes, or insulation. If motors are to function properly, they must be kept clean and dry. Dirt and moisture make good commutation impossible. Dirty and fouled starter motors may be caused by failure to replace the cover band, by water leakage, or by excess lubrication.

Most starter motors have a cover to protect the commutator and windings. If you neglect to replace the cover or remove it as an aid to ventilation and cooling, dirt and water are sure to damage the equipment.

Although lubrication of bearings is essential for proper operation, excessive lubrication may lead to trouble in a starter motor. Excess lubricant in the shaft bearings may leak or be forced past the seal and foul the insulating material, commutator, and brushes. The lubricant prevents a good electrical contact between the brushes and the commutator, causing the commutator to spark and heat and the brushes to burn.

Burned brushes are another possible source of trouble if the starter motor is inoperative. Burning may be caused by loose brush holders, improper brush spring tension, a brush stuck in the holder, a dirty commutator, improper brush seating surface, or overloading the starter.

STARTER MOTOR OPERATES BUT DOES NOT CRANK ENGINE

If the starter motor and battery are in good operating condition but the starter fails to crank the engine, the trouble will usually be in the drive connection between the motor and the ring gear on the flywheel. Troubles in the drive assembly are usually in the form of broken parts or a slipping clutch (if applicable). A slipping clutch may be the result of the engine not being free to turn or of the clutch not holding up to its rated capacity.

Even though seldom encountered, a stripped ring gear on the flywheel may be the source of trouble if the starter motor does not turn the engine.

ENGINE CRANKS BUT FAILS TO START

Starting troubles and their causes and corrections may vary to some degree, depending on the particular engine. If the prescribed prestarting and starting procedures are followed and a gasoline engine fails to start, the source of trouble will probably be improper priming or choking, a lack of fuel at various points in the system, or a lack of spark at the spark plugs.

Improper priming may be either underpriming or overpriming. Priming instructions differ, depending on the engine. Information on priming also applies to engines equipped with chokes. **A** warm engine should never be primed. Some engines may require no priming except when they are started under cold weather conditions.

On some installations, underpriming can be checked by the feel of the primer pump as it is operated On other installations, underpriming may be due to insufficient use of the choke.

Over-priming is undesirable because it results in a flooded engine and makes starting difficult. It also causes excess gasoline to condense in the intake manifolds, run down into the cylinders, wash away the lubricating oil film, and cause pistons or rings to stick

You can determine flooding by removing and inspecting a spark plug. A wet plug indicates flooding. If you find the engine to be flooded, be sure to dry out or deflood it according to prescribed instructions. Some installations specify that the ignition switch must be ON, while others state the switch must be OFF; therefore it is important for you to follow the engine manufacturer's instructions.

Improper carburetion may be the source of trouble if a gasoline engine fails to start. On some engines a check of the fuel pressure gauge will indicate whether lack of fuel is the cause. If the gauge shows the prescribed pressure, the trouble is not lack of fuel; if the gauge shows little or no fuel pressure, you should check the various parts of the delivery system to locate the fault.

In some installations, you can determine whether the trouble is in the gauge or in the fuel system by using the following procedure: (1) remove the carburetor plug next to the fuel pressure gauge connection; and (2) use a suitable container to catch the gasoline, and operate the pump used to build up starting fuel pressure. If fuel is reaching the carburetor, gasoline will spurt out of the open plug hole; this indicates that the gauge is inoperative. If no fuel flows from the plug opening, the trouble is probably in the fuel system somewhere between the fuel tank and carburetor. Even though all installations do not have a fuel pressure gauge, the procedure for checking the fuel system is much the same.

If a wobble pump is installed to build up starting fuel pressure, you can determine whether the pump is operating correctly by the feel and sound of the pump. If the pump feels or sounds dry, the trouble is between the pump and the supply tanks. The trouble might be caused by a clogged fuel line strainer or by an air leak in the line. If the wobble pump is pumping, the trouble may be in the line to the engine fuel pump or in the engine fuel pump itself.

Check the fuel lines for cracks, dents, loose connections, sharpbends, andclogging. You can remove the fuel line at the pump and use air to determine if the line is open.

Check fuel pumps for leaks at the pump gaskets ***or*** in the fuel line connections. Check fuel pump filters or sediment bowl screens for restrictions. Check the bypass for operation. If the bypass valve is defective, replace the fuel pump. In diaphragm-type fuel pumps, the filter bowl gasket, the diaphragm, or the valves may be the source of trouble. Check for air leaks in the diaphragm by submerging the discharge end of the fuel line in gasoline and looking for air bubbles while cranking the engine. If the engine will run, a leaky diaphragm is indicated by gasoline leakage from the pump air vent.

Carburetor trouble may be the cause if fuel does not reach the cylinders. You can check this by removing the spark plugs and looking for moisture. If there is no trace of gasoline on the plugs, the carburetor may be out of adjustment, the float level may be too low, or the jets may be clogged. If the fuel level in the carburetor float bowl is low, the float valve is probably stuck on the seat. If the fuel level in the float is correct, yet no fuel is delivered to the carburetor throat, the carburetor will have to be removed, disassembled, and cleaned.

Faulty ignition system parts may be the source of starting difficulties. You may encounter two kinds of ignition systems-the MAGNETO type and the BATTERY type. Even though the parts of these systems differ in some respects, their function is the same; namely, to produce a spark in each cylinder of the engine at exactly the proper time in relation to the position of the pistons and the crankshaft. Also, the system is designed so the sparks in all cylinders follow each other in proper sequence.

ENGINE FAILS TO STOP

If a gasoline engine fails to stop when the ignition switch is turned to the OFF position, the trouble is usually caused by a faulty ignition circuit, improper timing, the octane rating number of the fuel being too low for the design of the engine, or the engine being overheated.

In a magneto-type ignition system, an open ground connection may cause an engine to run after the ignition switch is turned off. When a magneto ground connection is open, the magneto will continue to produce sparks as long as the magneto armature magnets rotate, and the engine will continue to run. In other words, when the magneto ignition switch contact points are closed, the ignition should be SHUT OFF. This is not true of the booster coil circuit of a magneto-type system, nor of the usual battery-type ignition system. In these systems, an open ground or open switch points prevent current flow. If the switch of a battery-type ignition system fails to stop the engine, the contact switch points have probably remained closed.

If the ignition switch and the circuit are in good condition, failure to stop may be caused by overheating. If the engine is overheated, normal compression temperature may become high enough to ignite the fuel mixture even though no spark is being produced in the cylinders. When this happens in a gasoline engine, the engine is, in reality, operating on the diesel principle.

Normally, you will detect the symptoms of overheating before the temperature gets too high. The causes of overheating in a gasoline engine are much the same as those for a diesel engine.

Other troubles and their symptoms, causes, and corrections that may occur in a gasoline engine are similar to those found in a diesel engine. Troubles leading to the loss of rpm, irregular operation, unusual noises, abnormal instrument indications, and excessive consumption or contamination of the lube oil, fuel, or water can usually be handled in the same way for gasoline and diesel engines. Of course, there are always exceptions, so it is best to consult the manufacturer’s technical manual.

Most gasoline engines in the Navy are used by shore activities. Afloat, gasoline engines are used to drive portable pumps like the P-250, a piece of fire-fighting and dewatering equipment. Although pumps like the P-250 are primarily maintained by members of the Damage Controlman (DC) rating, Enginemen are involved to some extent in repairing or overhauling the P-250.

Before you disassemble a P-250 for repair, make sure that all the repair parts are available and on hand. When repairs are not within your ship’s force capability, you must turn the unit in to an IMA or SRF for repair. Attach an OPNAV 4790/2K (work order form) to the pump. Figure 3-45 illustrates a typical P-250 pump unit.

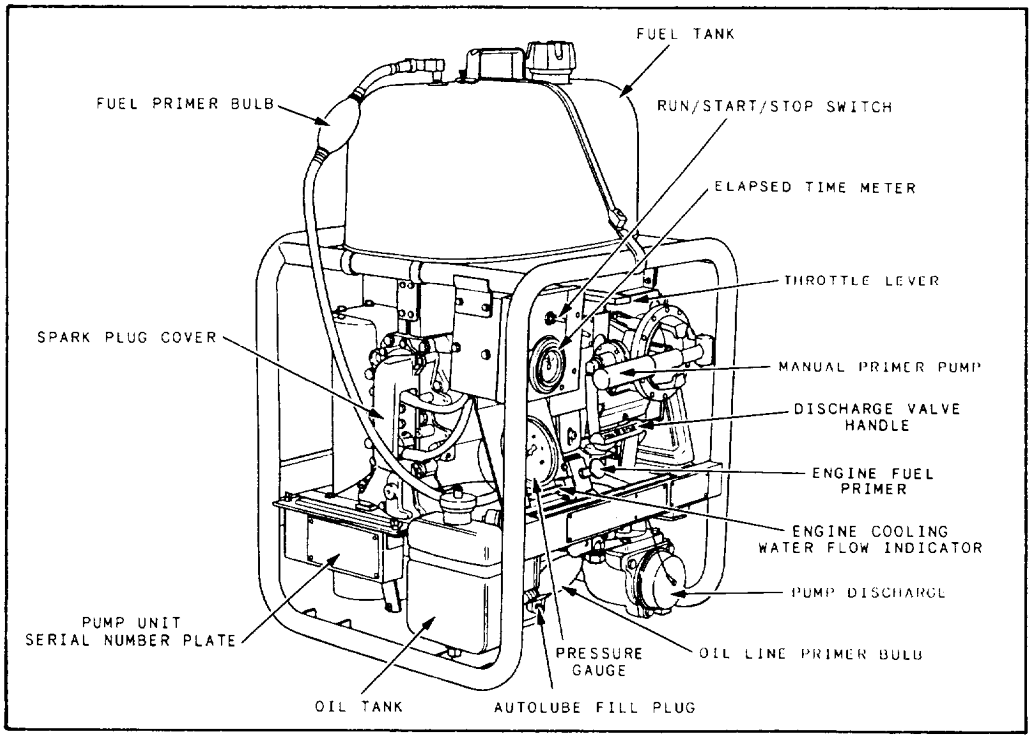


Figure 3-45.—A typical P-250 pump unit.

For more detailed information concerning operation, maintenance and repair of the P-250, refer to the NAVSEA technical manual, *Firefighter Pump P-250 Mod 1,* S6225-BW-MM0-010.

Some gasoline engines serve as outboard motors to power small boats. A high percentage of the motors' problems are electrical. A large number of problems are also caused by the use of fuel with a lower octane content than specified by the manufacturer. To gain knowledge about operating, maintaining, and repairing outboard motors, review manufacturers' service manuals and assigned PMS publications. Most outboard motor manufacturers offer a high quality training course, free of charge.

JACKING GEAR

The *Engineman 3,* NAVEDTRA 10539, introduced the two primary types of jacking gear, the ring gear, and the pinion assembly, and described their use. The only maintenance required for jacking gear is periodic inspection for wear and minor lubrication of the moving parts of the pinion assembly.

FUEL AND OIL PURIFIERS

Specific directions for operating a purifier are given in the manufacturer's instructions provided with the unit. The following information is general and applies to both the fuel and the oil purifiers.

For maximum efficiency, purifiers should be operated at their maximum designed speed and rated capacity. An exception to operating a purifier at its designed rated capacity is when the unit is used as a separator with 9000 series detergent oil. Some engines using the 9000 series oils are exposed to large quantities of water. When the oil becomes contaminated with water, it has a tendency to emulsify. The tendency to emulsify is most pronounced when the oil is new and gradually decreases during the first 50 to 75 hours of engine operation. During this period, the purifier capacity should be reduced to approximately 80 percent of its rated capacity.

Most oils used in Navy installations can be heated to 180°F without damage to the oils. Prolonged heating at higher temperatures is not recommended because such oils tend to oxidize at high temperatures. Oxidation results in rapid deterioration. In general, oil should be heated enough to produce a viscosity of approximately 90 seconds Saybolt universal (90 SSU), but the temperature should not exceed 180°F. The following temperatures are recommended for purifying oils in the 9000 series:

Military Symbol	Temperature (°F)
9110	140
9170	160
9250	175
9500	180

Pressure should not be increased above normal to force a high viscosity oil through the purifier. Instead, the viscosity should be decreased by heating the oil. Pressure in excess of that normally used to force oil through the purifier will result in less efficient purification. On the other hand, a reduction in the pressure that forces the oil into the purifier will increase the length of time the oil is under the influence of centrifugal force and, therefore, will tend to improve results.

DISCHARGE RING (RING DAM)

If the oil discharged from a purifier is to be free of water, dirt, and sludge and if the water discharged from the bowl is not to be mixed with oil, the proper size discharge ring (ring dam) must be used. The size of the discharge ring depends on the specific gravity of the oil being purified; diesel fuel oil, JP-5, and lubricating oils all have different specific gravities and, therefore, require different sized discharge rings. While all discharge rings have the same outside diameter, their inside diameters vary. Ring sizes are indicated by even numbers; the smaller the number, the smaller the ring size. The inside diameter in millimeters is stamped on each ring. Sizes vary in increments of 2 millimeters. Charts, provided in the manufacturers' technical manuals, specify the proper ring size to be used with an oil of a given specific gravity. Generally, the ring size indicated on such a chart will produce satisfactory results. If the recommended ring fails to produce satisfactory purification, you must determine the correct size by trial and error. In general, you will obtain the most satisfactory purification of the oil when the ring is the largest size that can be used without losing oil along with the discharged water.

MAINTENANCE OF PURIFIERS

Clean the bowl of the purifier daily according to the PMS, and carefully remove all sediment. The amount of dirt, grit, sludge, and other foreign matter in the oil may warrant more frequent cleaning. If you do not know the amount of foreign matter in an oil, have the purifier shut down and examined and cleaned once each watch, or more often if necessary. The amount of sediment found in the bowl indicates how long the purifier may be operated between cleaning.

Have periodic tests made to make sure the purifier is working properly. When the oil in the system is being purified by the batch process, tests should be made at approximately 30-minute intervals. When the continuous process of purification is used, tests should be made once each watch. Analysis of oil drawn from the purifier is the best method of determining the efficiency of the purifier. However, the clarity of the purified oil and the amount of oil discharged with the separated water will also indicate whether the unit is operating satisfactorily.

SUMMARY

This chapter covered the general procedures concerning repairs, troubleshooting, maintenance, and overhaul of internal combustion engines. Additionally, it covered the general maintenance of jacking gear and fuel and oil purifiers. Read and use the correct references, such as the manufacturers' manuals and the PMS to operate and care for your equipment.